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# Human Population Exposures to Mirex and Kepone

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16. ABSTRACT

Human exposures to mirex and kepone are assessed in this study. Three major paths of exposure are examined: ingestion through the food chain, inhalation of atmospheric mirex and kepone, and exposure through drinking water.

Exposure through the food chain appears to be the most pressing current problem. Various species of commercially caught fish in certain areas of the country have been found to contain slight amounts of the compounds. It is difficult to obtain estimates of the human exposure from sport fish, but evidence seems to suggest that sportsmen and their families may be exposed through fish. Also, game captured in the southeastern U.S. has been found to contain the compounds. Kepone has been found in mothers' milk in some areas of the country.

Atmospheric exposures are not considered terribly great now, since the compounds are no longer produced and the major atmospheric exposures are believed to be occupational exposure at the producing factory and exposure to workers' families from clothing, etc.

Human exposure to mirex and kepone from drinking water supplies does not appear to be a problem, since both compounds are very insoluble in water.

Exposure through tobacco was also considered.

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# I INTRODUCTION

The primary objective of this study has been to quantify the mirex and kepone doses to the U.S. population in general and to identify and characterize specific subgroups of the population that may be receiving the largest exposures.

This is one in a series of studies being conducted by SRI to quantify populations at risk to selected pollutants. These studies are generally conducted on a quick-response basis to provide input to other, more inclusive studies.

The quantitative nature of this study required the collection and assimulation of monitoring and surveillance data for various exposure media. Because much of the environmental concentration data regarding mirex and kepone contaminations have been only recently collected, and have not yet been published, a significant part of this study involved contacting sources throughout the country to obtain their most recent data. No doubt additional data will soon be released that could aid in better characterizing the population exposures. In fact, insufficient data have made it impossible to estimate exposures for several areas that may be important.

In this report, human mirex and kepone dosages have been given in terms of total exposure. Note that this study reports exposures that took place before biological sorption occurred, and that the degree of such sorption is not considered. The major human exposure routes evaluated are oral (e.g., food and water) and inhalation.

The main findings of this report are in the form of tables and figures. The text has been provided to describe the methodologies, assumptions, and data sources used. All estimates given in this report depend in a large degree on the reliability and availability of data, which varied widely.

# II SUMMARY

## A. Overview

Mirex and kepone are two closely related chemical compounds synthesized from hexachlorocyclopentadiene. Neither has been found to occur naturally in the environment; hence, all environmental contamination is attributable to anthropogenic activities related to the manufacture and use of the two compounds and their products. The highest localized concentrations and the greatest environmental concerns of consequence result from discharges into water systems by manufacturers. Other environmental contaminations result from using the compounds in pesticide formulations on large areas of land. Mirex and kepone are readily adsorbed onto suspended solid particles that may be eaten by aquatic organisms, thereby ultimately entering the human food chain. Mirex and kepone, like many other chlorinated organic compounds, are only slightly soluble in water but are soluble in fats and oils. Because of this, they will usually migrate to portions of the environment that are high in fats and oils. Because most biological organisms contain fats and oils, mirex and kepone tend to accumulate at much higher levels in these substances than exist in the environment. This bioaccumulation, along with their nonbiodegradability, make the compounds of special concern for ecological and health considerations. Both compounds have been found to be quite stable in the environment and may have half-lives of a decade or more. Kepone is one of the degradation compounds of mirex, and basic mirex material has been found to be kepone-contaminated.

The main manufacturers of mirex have been the Hooker Chemicals & Plastics Corp. at Niagara Falls, New York, and the Nease Chemical Company at State College, Pennsylvania. Most production took place from 1959 to 1974. The basic material is not currently produced; however, existing stockpiles are sufficient to supply demand for some time. Mirex has been used to manufacture mirex pesticides and Dechlorane, which has been used primarily as a fire retardant. Almost three times more mirex has been sold for making Dechlorane than for pesticide use. The potential environmental contamination from the formulation of Dechlorane in products and from the use of such products remains largely unaddressed. The main use of the mirex pesticide has been in bait for controlling the imported fire ant (Solenopsis saerissima) in a nine-state infested area in the southeastern United States (Mississippi, Alabama, Arkansas, North Carolina, South Carolina, Florida, Georgia, Louisiana, and Texas). Application has covered more than 10 million acres per year (some of these acres have been counted more than once because of multiple applications of the pesticide bait). Mirex bait is also used in Hawaii to control the pineapple mealybug (about 30,000 acres of crop per year has been treated). Other uses have included control of the western harvester and the the Texas leaf-cutting ant.

Kepone's main manufacturers have been the Allied Chemical Company at Baltimore, Maryland and Hopewell, Virginia; the Life Sciences Products Company at Hopewell, Virginia; Nease Chemical Company at State College, Pennsylvania; and the Hooker Chemicals & Plastics Corp. at Niagara Falls, New York. Most production of the basic kepone material occurred from 1958 to 1975. It is no longer manufactured; however, stockpiles are sufficient to meet demands for several years. The major use of kepone in the continental United States is as roach and ant bait in houses, and on lawns and gardens. It is still registered for these uses. Although no longer so registered, it was registered for use on nonbearing citrus for control of the rust mite; on tobacco for control of the southern potato wireworm and the tobacco wireworm; and on gladiolli and other plants. A major, primarily non-United States, use is for the control of the banana root borer in many banana producing countries, including the U.S. territory of Puerto Rico.

Seafood* taken from selected contaminated areas has been found to be the greatest environmental source of mirex and kepone for most people. Mother's milk in three southeastern states (North Carolina, Alabama, and

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*The term "seafood" as used in this report indicates finfish, shellfish, and crustacea, taken from fresh and salt waters.

and Georgia) has been found to contain kepone residues. Certain game, taken from areas in the southeastern United States in which mirex bait has been applied, has been found to be mirex-contaminated. Other foods have either been tested for mirex and kepone and found uncontaminated or have not been tested.

Human environmental atmospheric exposures apparently existed during manufacture of the two basic compounds. However, environmental atmospheric sampling has only been conducted for kepone in Hopewell and nowhere for mirex. Because the compounds are no longer manufactured, such exposures no longer exist. Use of kepone bait for indoor ant control may result in extremely low concentrations in the air of dwellings so treated.

Human exposure to mirex and kepone from tobacco appears not to be a problem.

Drinking water has not been found to be mirex-contaminated. Unfiltered drinking water taken from the lower James River in Virginia may contain kepone concentrations, on the order of 0.1 to 10 ppb, that are probably associated with concentrations on the suspended solids since both compounds are relatively insoluble in water.

Tables II-1 and II-2 summarize potential mirex and kepone exposures for various populations at risk. These exposures are summarized in the remaining paragraphs of this chapter and are described in more detail in the following chapters of this report.

## B. Mirex in Foods

The established tolerances for mirex in foods is 0.1 ppm in fat and meat from cattle, goats, hogs, horses, poultry, and sheep; 0.1 ppm in eggs; 0.1 ppm in milk fat; and 0.01 ppm in all agricultural commodities, exclusive of eggs, milk fat, and animal fat. The 0.1 ppm limit has also been applied to finfish.

Mirex has been found in seafood taken from Lake Ontario and the St. Lawrence River in New York, from Spring Creek in Pennsylvania, and from areas in the southeastern United States where mirex bait has been applied. Mirex has also been found in game taken in the Southeast.

## Table II-1

## HUMAN POPULATION EXPOSURES TO ENVIRONMENTAL MIREX

| Source | Average Environmental Concentrations | Calculated Average Adult Daily Exposure | At-Risk Population |
|---|---|---|---|
| Food | | | |
| Lake Ontario seafood | <0.01-0.2 ppm | 0.05 μg[1]<br><0.34 μg[2] | <1 million |
| St. Lawrence seafood | 0.02-0.10 ppm | 0.06 μg[1]<br><0.39 μg[2] | <100 thousand |
| Southeastern seafood[3] | 0.01-0.03 ppm | 0.02 μg[1]<br><0.13 μg[2] | <4.5 million |
| Spring Creek fish[4] | 0.02-1.00 ppm | 0.02-0.09 μg[1]<br>0.12-5.80 μg[2] | very few |
| Southeastern wildgame[3] | <0.06 ppm | <12 μg[5]<br><0.1 μg[10] | <9 million |
| Atmospheric | | | |
| Basic product manufacturing neighborhoods | NE[6] | NE[6] | 130,000 |
| Areas of mirex bait application | <0.006 ng/$m^3$[7] | <0.09 ng[7] | <300,000 |
| Drinking Water | | | |
| No contaminated supplies found | <0.1 ppb[8] | <0.15 μg[8] | NE |
| Tobacco | | | |
| No concentrations reported | <1 ppt[9] | 0.004 ng[9] | <35% of U.S. adults |

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[1] Based on freshwater finfish consumption.

[2] Based on all finfish consumption.

[3] Game or fish taken from areas in which mirex bait has been applied.

[4] Catch taken near the Nease plant.

[5] Considered an extreme overestimate, based on wildgame fulfilling the requirement for all meat in the diet.

[6] Not estimated; exposures no longer exist.

[7] Considered to be an upper limit.

[8] This is the lower limit of detection for most sampling; no water supplies were found at this concentration.

[9] An estimate based on plant root uptake data; no concentration data have been reported.

[10] Average per capita consumption.

## Table II-2

## HUMAN POPULATION EXPOSURES TO ENVIRONMENTAL KEPONE

| Source | Average Environmental Concentrations | Calculated Average Adult Daily Exposure | At-Risk Population |
|---|---|---|---|
| **Food** | | | |
| James River seafood[1] | 0.4-2.0 ppm, finfish<br>0.3-3.0 ppm, crabs<br>0.1-0.2 ppm, oysters | 1.1 μg[2]<br>8.5 μg[3] | NE[4] |
| Chesapeake Bay seafood | 0.0-0.08 ppm, finfish<br>0.008-0.05 ppm, oysters<br>0.10-0.26 ppm, crabs | 0.3 μg[2]<br>3.5 μg[5] | 5-10 million |
| Select East Coast Atlantic Ocean fish | 0.01-0.04 ppm[6] | <0.27 μg[7] | >570,000 |
| Spring Creek fish[8] | 0.025-0.23 ppm | 0.02-0.20 μg[9]<br>0.14-1.33 μg[10] | very few |
| Mother's milk | <3 ppb | 0.6-1.9 μg | 3,300 |
| **Atmospheric** | | | |
| Basic product manufacturing neighborhoods | <50 μg/m$^3$[11] | <750 μg[11] | 115,000 |
| Indoor ant bait use | <0.3 ng/m$^3$[12] | <4.5 ng[12] | <6-12 million/yr combined |
| Indoor ant trap use | <9 ng/m$^3$[12] | <135 ng[12] | |
| **Drinking Water** | | | |
| Lower James River | <0.1-10 ppb | <0.15-15 μg | very few[13] |
| **Tobacco** | | | |
| No concentrations reported | 1 ppt[14] | 0.004 ng[14] | <35% of U.S. adults |

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[1] The James River estimates assume that the river is open with no restrictions.
[2] Based on consumption on a species basis.
[3] Based on eating only seafood taken from the James.
[4] Not estimated because the river is currently closed to the taking of many species.
[5] Based on eating only seafood taken from the Bay.
[6] Mainly bluefish.
[7] Based on consuming only bluefish as the entire finfish component of the diet.
[8] Catch taken near the Nease plant.
[9] Based on freshwater finfish consumption.
[10] Based on all finfish consumption.
[11] These exposures no longer exist because the basic product is no longer manufactured.
[12] Due to volatilization, concentrations could be higher due to suspension of detached bait particles.
[13] Although these concentrations have been reported for the James, they are not applicable to any municipal water supply.
[14] The estimate is based on plant root uptake data; no concentration data have been reported.

It has not been found to be a problem for Hawaiian foods, nor has it been found to constitute a problem in other foods including mother's milk. Of 1436 samples of mother's milk taken nationwide and representing all 50 states, none was found to contain mirex at the 30-ppb detection level.

Lake Ontario is currently closed to the taking of many species of fish because of mirex contamination. This does not mean that it will permanently remain closed; it has recently been opened to some additional species. Nor has it been closed to Canadian fishing, except for commercial fishing of coho and chinook salmon. Average mirex concentrations, by species, in Lake Ontario fish range from none to 0.27 ppm, with an overall average of 0.10 ppm.

It is estimated that on the average, people who eat Lake Ontario fish consume 0.05 μg/day of mirex. An average person eating finfish taken only from the lake would consume 0.34 μg/day of mirex. Based on variations in fish consumption by individuals, 10% of the consuming population might ingest 0.49 μg/day or more of mirex.

The 1974 U.S. commercial catch from Lake Ontario could supply the entire finfish requirements for 70,000 people. The sports fishing catch has not been estimated but probably exceeds the commercial catch. An estimated 500,000 to 1 million people annually might consume some sports fish taken from the lake.

Depending on species, fish taken from the St. Lawrence River have shown average mirex concentrations of 0.02 to 0.10 ppm. It is estimated that on the average, people who eat St. Lawrence fish consume 0.06 μg/day of mirex. An average person eating finfish taken only from the river would consume 0.39 μg/day of mirex. Based on variations in fish consumption by individuals, 10% of the consuming population might ingest 0.57 μg/day or more of mirex. The size of the consuming population is not known; however, sports fishing is a major industry for local communities. The greatest exposure would be to an estimated 50,000 to 100,000 people.

The mirex consumption for St. Lawrence fish is estimated to be slightly larger than for consumption of Lake Ontario fish. This is contradictory to the fact that the major mirex discharges were into the lake rather than the river. It is due to the broader representation of species sampled from the lake, some of which contained little or no mirex and were not sampled from the river.

Mirex concentrations of 0.02 to 1.0 ppm have been found for fish taken from Spring Creek near the Nease chemical plant. Few people are estimated to consume fish taken from Spring Creek. It is estimated that on the average, people who eat these fish consume 0.02 to 0.09 μg/day of mirex.

Mirex concentrations have been found in fish taken from areas in the southeastern United States where mirex bait has been applied. Specifically, mirex has been found in fish taken from Alabama, Arkansas, Georgia, Louisiana, Mississippi, and South Carolina. In general, the concentrations of mirex have been higher in fish taken from treated areas within a state than in fish taken from untreated areas within the same state. Moreover, concentrations are higher shortly after application than they are several years after application. However, sampling tends to indicate that average concentrations on the order of 0.01 to 0.03 ppm in finfish will persist at least for several years after application. It is estimated that on the average, people who eat these fish consume 0.02 μg/day mirex. Based on variations in fish consumption by individuals, 10% of the consuming population might ingest 0.20 μg/day or more of mirex.

Game taken from southeastern states where mirex has been applied have also been found to be mirex-contaminated, suggesting another source (in addition to fish) of mirex for sportsmen and their families. Data for cottontails, opossums, bobwhite quail, deer, and turkey have shown average mirex concentrations of around 0.04 ppm for samples taken 1 year after bait application. These concentrations are generally found in adipose tissue and are somewhat similar to those for finfish taken from the same area. If it is assumed that contaminated game comprise a family's entire meat, fish, and poultry supply, the average adult exposure would be 8 to 12 μg/day of mirex, and the 1 year old infant exposure would be 2 μg/day. These exposures are believed to be gross overestimates because very few people would eat only contaminated game. The average exposure is estimated to be 0-0.1 μg/day. It has been estimated that approximately

9 million people might be at risk to eating at least some game taken from these areas.

Residents of Hawaii may consume some mirex from foods contaminated by the mirex bait used to control the pineapple mealybug. Estimating the magnitude of exposure and the exposed population sizes is impossible with available data; however, as a rough estimate it has been calculated that human exposures from these sources would be much less than 1 μg/day. The exposed population would probably be quite small.

Of 300 fish samples analyzed from Lake Erie, none was found to contain detectable levels of mirex. This was not unexpected since there were no known discharges into the lake. It is, however, evidence on the bounds of the pervasiveness of the compound in the environment.

## C. Kepone in Foods

The established tolerances for kepone concentrations in foods pertain to aquatic organisms and are as follows: 0.3 ppm for shellfish, 0.3 ppm for finfish, and 0.4 ppm for crabs.

Because kepone is used to control the banana root borer (the only current food or feed use of kepone), a limit of 0.01 ppm has been established for banana peels. This limit is presumed to result in kepone concentrations of less than 0.005 ppm in banana meat.

Seafood and mother's milk from selected locations are the only foods that have yet been found to be kepone-contaminated. The contaminated fish are from the James River and Chesapeake Bay, as well as Atlantic Ocean fish that may reside part of the time in these waters. Contaminated mother's milk has been found in three southeastern states.

Until recently the lower James River was closed to the taking of most seafood except oysters; it is now open for some other species. Kepone concentrations in James River oysters have averaged 0.1 to 0.2 ppm; finfish concentrations have averaged 0.04 to 2.0 ppm, depending on species; average kepone concentrations in crabs have been reported as 0.3 to 3.0 ppm. Current population exposure to kepone from eating James

River fish is small. If, however, the river was reopened for all fishing the average consumer would ingest 1.1 μg/day of kepone. Based on variations in fish consumption by individuals, 10% of the consuming population would ingest 3.5 μg/day of kepone or more.

The Chesapeake Bay is not closed to fishing, but commercial catches are monitored to determine if kepone concentrations are below action levels. Average kepone concentrations in Chesapeake Bay finfish have generally been found to be 0.01 to 0.08 ppm, depending on species; average kepone concentrations in oysters have variously been reported as 0.008 to 0.5 ppm; and average kepone concentrations for crabs have been reported at 0.10 to 0.26 ppm. Based on these data and expected fish consumption, it is estimated that an average person eating seafood from the Bay will consume 0.3 μg/day of kepone, whereas based on variations in fish consumption by individuals, people in the upper 10% of the fish-consuming population will ingest 1.0 μg/day of kepone. These results assume that species required in the average survey diet and not available in the Bay will be purchased from supplies caught elsewhere. The Chesapeake Bay is an active area for commercial and sportsfishing. The combined sports and commercial catch from these waters can supply the average annual requirements of 4.9 million people for finfish, 8.7 million people for crabs, and 26.5 million people for oysters.

Certain fish such as bluefish, spot, croaker, striped bass, striped mullet, grey trout, and speckled trout can reside part time in the James River and/or Chesapeake Bay and part time in the Atlantic Ocean. Fish caught in the Atlantic after residing in these contaminated waters would also be expected to be kepone-contaminated. Bluefish samples collected along the Atlantic coast from Boston to Ft. Lauderdale have been evaluated for kepone. Average kepone concentrations by collection locations ranged from none to 0.04 ppm. The highest concentrations were found in the Virginia samples, with decreasing amounts recorded as distance from Chesapeake Bay increased. These species that reside part time in the Bay or James and part time in the Atlantic Ocean have been estimated to have average kepone concentrations of 0.02 to 0.04 ppm for catches taken close to the Bay. The commercial catch of these species taken from this location could supply the entire finfish dietary needs of 180,000 people, whereas the sports and commercial bluefish catch taken over the larger coastal area could supply the entire finfish requirements of more than 500,000 people. Generally, these species make up only a small fraction of an individual's seafood diet; hence, substantially more people than indicated above could be exposed to at least some ingested kepone. People eating only these species as the total finfish component of their diet would have an average daily exposure of approximately 0.13 to 0.27 µg/day. This, of course, greatly overestimates the actual exposure for most consumers.

Kepone concentrations of 0.025 to 0.23 ppm are reported for fish taken from Spring Creek near the Nease chemical plant. The population consuming these fish is small; however, these concentrations could result in an estimated average kepone intake of 0.02 to 0.20 µg/day.

Fish taken from other locations, including Lake Ontario and the inland Southeastern United States, have seldom been found to be kepone contaminated.

Approximately 3.9, 7.5, and 2.6% of the mothers in North Carolina, Alabama, and Georgia, respectively, have been found to have kepone in their milk. Kepone was not detected in milk samples taken from seven other southeastern states. The average concentrations for the positive samples ranged between 1 to 3 ppb. These concentrations would result in an estimated consumption of 0.6 to 1.9 µg/day for a population of about 3300 infants. These estimates are only relevant for the 10 states in which mother's milk has been tested for kepone. Other states (particularly in the Northeast) might also be suspected because fish consumed in these areas may also be kepone contaminated.

Household ants or roaches may eat or carry off particles of kepone bait. If the animal should die in the house, this kepone could pose a potential human exposure route. The insect may be eaten by children or may accidently be included in foods during their preparation. The contaminated insect parts or the bait particles carried off may also be incorporated in household dust, resulting in inhalation exposure. No data are available, however, to indicate the potential magnitude of such exposure, which would depend on the number of ants or roaches killed and on housekeeping practices. The potential ingestion exposure could be significant (one ant might contain as much as 12.5 μg of kepone), but it might also be infrequent.

Residents of Puerto Rico may have some exposure to kepone because of animal contamination from kepone used in control of the banana root borer. No environmental monitoring data have been recorded for Puerto Rico; hence, there is no proof that such exposures actually exist. Based on the mirex data for Hawaii, and on other test results, it is possible that such animals might be kepone contaminated on the ppm level.

## D. Atmosphere Exposures

Atmospheric concentrations of mirex and, especially kepone, posed an occupational hazard during product manufacture. Kepone concentrations as high as 3 $mg/m^3$ have been reported in the Life Sciences plant when it was in operation. The current NIOSH standard is 1 $\mu g/m^3$. Neighborhood environmental atmospheric kepone concentrations as high as 50 $\mu g/m^3$ of air were measured when the Hopewell Life Sciences plant was in operation, with readings as high as 30 $ng/m^3$ recorded 25 km from the plant. Environmental atmospheric concentrations of mirex or kepone were probably also present in State College, Pennsylvania, Niagara Falls, New York, and Baltimore, Maryland, when the basic product was manufactured at these locations; however, no measurements are reported. It is estimated that approximately 155,000 people have been at-risk to atmospheric kepone concentrations at some time and that 130,000 of these same people were at-risk to atmospheric mirex.

Families are also thought to have been exposed by workers wearing their contaminated clothing home. Because the basic products are no longer manufactured, the sources and the exposures no longer exist.

Because mirex bait is only dispensed through the air when associated with relatively coarse corn cob grit particles, which settle rapidly, amounts remaining airborne should be insignificant. With mirex's high melting point and low vapor pressure, volatization from bait on the ground should also be insignificant. No atmospheric concentrations have been reported for areas when bait was applied. Rough order calculations indicate that the atmospheric concentration should be much less than 0.006 ng/m$^3$ in the first hours after application. Exposed human populations are estimated to have been on the order of 230,000 to 330,000 per year.

Kepone ant and roach bait and traps may be used indoors or outdoors. Indoor use may result in atmospheric contamination or contamination of food and water. Accidental exposures may also result, particularly to children from tasting or eating the material contained in the traps or bait. No indoor atmospheric concentrations have been reported for rooms in which kepone bait and traps have been used. Rough order calculations indicate that due to volatization, the concentrations should be less than 0.3 ng/m$^3$ for rooms in which enclosed traps have been used and less than 9 ng/m$^3$ in rooms in which unenclosed bait has been used. These concentrations might be further increased from the volatization and atmospheric suspension of bait particles carried away from the traps by insects. These calculated concentrations are expected to be gross overestimates. The remaining supplies of kepone are estimated to be sufficient to meet the ant and roach bait and trap demand for 3 years. Use of this material could result in as many as 6 to 12 million person exposures per year if all the material was used indoors.

About 12.5 cases per year have been reported that involve young children and kepone products. In almost all episodes involving traps, the children were found chewing the cans without any indication that they had ingested the contents. Assuming that only 1% of the cases are reported implies that there might be 1250 such cases per year. Assuming that the can is partially full, each child might eat 5 mg of kepone, or about 6.7 ppm in their diet for that day.

## E. Tobacco

No data have been found to indicate the presence of mirex or kepone in tobacco. Both chemicals might be found in the soils of tobacco fields because mirex has been used in the Southeast to control the imported fire ant and kepone has been used on tobacco for control of the southern potato wireworm and the tobacco wireworm. Studies have shown that plants can take up mirex. Based on the uptake data and the application rates of the pesticides, concentrations on the order of parts per trillion might be found in tobacco from selected locations. In laboratory tests approximately 23% of the mirex added to cigarettes was recovered unaltered in the mainstream smoke. Assuming a mirex concentration of 1 ppt in the tobacco, leads to an estimated daily inhalation of 4.4 pg for average male smokers and 3.6 pg for average female smokers. These exposures are pure speculation because it is not known whether or not mirex or kepone are still present in tobacco field soils, whether tobacco plants will take up mirex or kepone, and what concentrations may actually be present in tobacco.

## F. Drinking Water

Mirex and kepone concentrations in drinking water have not been found to constitute a significant human exposure. Both are relatively insoluble in water and both are rapidly adsorbed onto sediments. The only human exposures would probably occur from ingesting mirex or kepone adsorbed onto the sediments during periods of extreme turbidity and with little filtration. Numerous drinking water samples taken in areas where mirex was manufactured or used have failed to show a concentration at the 0.1-ppb detection level.

The major area of concern in regard to kepone contamination of drinking water is for people who take their drinking water from the James River. Tap water taken from the Hopewell area contained no detectable kepone at the time of sampling. Ice samples and other water samples taken directly from the James River have shown kepone concentrations of 0.1 to 10 ppb. Similar concentrations have been found for samples taken at other locations on the James. These were probably on the suspended particles and, hence, filterable. Persons drinking water contaminated to these concentrations would ingest, on the average, 1.5 to 150 ng/day of kepone. Because Hopewell is the only municipality that takes its drinking water from the lower James and because its processed water has been found to be free of kepone, the at-risk population should be very small.

## G. Mirex and Kepone in Human Bodies

The ultimate confirmation that environmental concentrations of mirex and kepone are entering and residing in human bodies comes from the monitoring of human tissue, blood, and mother's milk. Evaluation of 284 human adipose tissues for mirex has shown 52 (18%) positive. The mirex residue concentration in the positive samples ranged between trace amounts and 1.32 ppm. Of 1435 mother's milk samples taken throughout the country, none was shown to contain detectable concentrations of mirex. However, 9 out of 298 (3%) mother's milk samples tested contained kepone residues of 1 to 5.8 ppb. Venous blood samples were drawn from 216 people who reside within 1 mile of the Life Sciences plant site in Hopewell but who do not work at the plant. Of these, 40 (19%) contained kepone concentrations of 5 to 50 ppb.

## III SOURCES OF ENVIRONMENTAL CONTAMINATION BY MIREX AND KEPONE

### A. General

All environmental concentrations of mirex and kepone are attributable to anthropogenic activities related to the manufacture and use of the two compounds and their products. The current highest localized concentrations and resulting greatest environmental concerns result from discharges into the water systems by the manufacturers. Because mirex and kepone are readily adsorbed onto suspended solid particles, which may in turn be consumed by aquatic organisms, the primary major human exposure is from eating such organisms. Because the compounds are adsorbed on solids that can settle or be filtered, the contamination of drinking water appears to be minimal. Environmental air contamination appears not to have been addressed during manufacture of the basic mirex and kepone compounds; it is not, however, a current problem because production of the basic compounds has ceased.

Other human exposures have and continue to result from mirex and kepone products that have contaminated plants and aquatic and terrestrial animals. This is primarily the case for mirex that has been applied to vast areas in the southeastern United States to control the imported fire ant.

Environmental contaminations by mirex and kepone are aggravated by their persistence in the environment. Both have half-lives that may exceed a decade. Moreover, their degradation products may also be of environmental concern. For example, mirex partially degrades into kepone.

The pathways of potential human exposure and the geographical locations of concern are discussed below.

## B. Environmental Contamination from Manufacturers

### 1. Mirex

Mirex has been sold not only as an insecticide but also as an industrial fire retardant under the trade name Dechlorane (Markin et al., 1972a). A complete list of past mirex product manufacturers and their production is unavailable because of these manufacturers' reluctance to release such information and the government's desire to protect the confidentiality of individual companies.

Since 1959, the Hooker Chemical Company plant at Niagara Falls, New York, has manufactured a substantial amount of mirex, with heaviest production from 1962 to 1968. In this period, presumably the largest amount of mirex was discharged with wastewater. From 1968 to April 1975, mirex was only ground to powder and packaged at the Hooker plant. It was shipped to the plant in bulk from Nease Chemical Company, State College, Pennsylvania, and from Hexagon Laboratories of New York City. The company currently has 147 tons of mirex stored at its Niagara Falls, New York, plant (Chemical Week, Nov. 3, 1976). Grinding, which is a clean operation when compared with manufacturing, is a dry process. The equipment and room are washed down afterwards, with building drains passing through a sewer into the Niagara Falls sewage treatment plant. The Hooker plant released an estimated 1.4 lb/day (0.6 kg) of mirex during this grinding operation (Forest, 1976). However, Hooker estimates their release to be 0.018 lb (once per year) (Chambers, 1976). The Niagara Falls sewage is released in the Niagara River which flows into Lake Ontario. Lake Ontario empties into the Atlantic Ocean through the St. Lawrence River. As will be shown later, fish and sediments in all of these inland water bodies are mirex-contaminated.

The Nease Chemical Company at State College, Pennsylvania, manufactured mirex during 1966 to 1974. Some of the chemical produced is apparently stored by Nease and has been sold periodically to the Hooker Chemical and Plastics Company. Hooker reports purchasing 1,534,020 lb of the material from Nease during 1966 to 1974, as follows (Chambers, 1976):

April 1966 - end year (250,000 lb)
November 1968 - June 1969 (715,240 lb)
January 1973 - June 1974 (568,780 lb).

The Nease plant is located near Spring Creek. Concentrations of mirex has been found in fish and sediments sampled as many as 18 mi downstream from the plant in Spring Creek. Spring Creek flows into Bald Eagle Creek, which flows in turn into the West Branch of the Susquehanna River, the Susquehanna River itself, and thence into the upper Chesapeake Bay.

Mirex may have also been manufactured at the Allied Chemical Company formulation facility in Baltimore, Maryland. There are, however, no reported data indicating that it actually was manufactured there. Discharges from the plant could have entered upper Chesapeake Bay.

Hooker also reports purchasing 50,000 lb of mirex from Hexagon Laboratories, New York, New York (Chambers, 1976). To date it has not been determined if Hexagon made or purchased the mirex or if they sold the compound to others.

Manufacturer of mirex bait used in fire ant control was carried out by the Allied Chemical Company in Aberdeen, Mississippi. Allied sold this plant to the State of Mississippi in 1975. Since then, Mississippi has been operating the plant as the sole U.S. producer of mirex bait. It plans to phase out mirex production by June 30, 1978 (Toxic Materials News, October 27, 1976). Possible local environmental contaminations from the operation of this plant are not addressed here because no supporting data exist.

Mississippi's Aberdeen Prairie Plant can produce 60 to 70 tons of mirex bait in a one 8-hour shift. Production could be increased by adding another shift (Pesticide Chemical News, May 12, 1976). The plant's 1976 mirex production is estimated to be 10,200 tons. This amount would be sufficient to treat more than 16,300,000 acres at a rate of 1.25 lb/a (Pesticide Chemical News, August 4, 1976).

Hooker's sales of mirex and Dechlorane for 1959 to 1975 are shown in Table III-1. During 1959 to 1975, 880,319 lb of mirex were sold

Table III-1

## HOOKER CHEMICALS AND PLASTICS COMPANY SALES OF MIREX AND DECHLORANE ($C_{10}Cl_{12}$) BY YEARS

| Year | Mirex Sales (lb) | $C_{10}Cl_{12}$ Sales (lb) | Total Sales (lb) |
|---|---|---|---|
| 1959 | -- | 100 | 100 |
| 1960 | -- | 1,793 | 1,793 |
| 1961 | 200 | 8,737 | 8,937 |
| 1962 | 12,000 | 79,033 | 91,033 |
| 1963 | 25,500 | 284,933 | 310,433 |
| 1964 | 26,000 | 463,033 | 489,033 |
| 1965 | 54,000 | 541,691 | 595,691 |
| 1966 | 69,120 | 331,172 | 400,292 |
| 1967 | 72,600 | 159,438 | 232,038 |
| 1968 | 62,100 | 278,404 | 340,504 |
| 1969 | 102,000 | 72,320 | 174,320 |
| 1970 | 58,000 | 45,610 | 103,610 |
| 1971* | 30,000 | 82,040 | 88,910 |
| 1972 | 135,665 | 119,970 | 255,635 |
| 1973 | 113,000 | -- | 113,000 |
| 1974 | 80,000 | 2,850 | 82,850 |
| 1975 | 40,134 | 10,250 | 50,384 |
| Total | 880,319 | 2,481,374 | 3,338,563<br>(3,361,693)* |

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*Note: The reported 1971 data err because the sum of the parts exceeds the total. The figure in parentheses assumes a production of 112,040 lb in 1971.

Source: Chambers (1976).

for use as a plasticizer and flame retardant under the trade name Dechlorane. Hence, only about 25% of the material was sold as a pesticide. The extent to which Dechlorane was incorporated into other products is unknown. It was advertized for use in a wide variety of subjects ranging from paints to papers, although it appears to have been used primarily in butyl rubber, pyrotechnic mixtures, and plastics (Markin et al., 1972a). Dechlorane would have been enclosed in many of these products and thus might not contribute significantly to environmental contamination.

Manufacturers of products containing Dechlorane may also have emitted the chemical to the environment, where it could not be distinguished from mirex. As an example, the Armstrong Cork Company of Volney, New York, tested Dechlorane in 1961 (Syracuse Herald-Journal, Jan. 6, 1977). They had purchased 1000 lb for their testing (McManus, 1977). Armstrong discharges wastes into the Oswego River, which flows into Lake Ontario. Elevated levels of mirex have been found in the Lake Ontario sediments near the area where the Oswego flows into the lake (Forest, 1976). It has not been possible to compile a complete list of manufacturers who purchased Dechlorane; however, Hooker's 1975 sales of Dechlorane ($C_{10}Cl_{12}$) are as follows (Chambers, 1976).

| Buyer | Destination | Sales (lb) |
|---|---|---|
| Canadian Government, Department of National Defense | Valacartier, Gro.-Iro., Quebec | 250 |
| Celesco Industries | Highland Industrial Park, East Camden, Arkansas | 6250 |
| Day and Zimmerman | Lone Star Division Texarkana, Texas | 3750 |

## 2. Kepone

Kepone was originally manufactured by the Allied Chemical Company at their formulation facility in Baltimore, Maryland. Original patents were granted in 1952. It was first registered as a pesticide with USDA in 1959. Allied also subcontracted manufacture to Nease Chemical Company (State College, Pennsylvania), which manufactured it from 1958 to 1963 (Toxic Materials News, Aug. 18, 1976), and to the Hooker Chemical Company (Niagara Falls, New York), which manufactured it from 1963 to 1965 (Chambers, 1975). In 1966, Allied shifted production to the Semi-Works located at the chemical complex at Hopewell, Virginia (Kelly, 1976) where production continued until 1973. Increasing demand for kepone, particularly from Europe, and a need for the Semi-Works facility led to the transfer of manufacture to the Life Science Products Company of Hopewell, Virginia. Life Sciences manufactured kepone for a 16-month period in 1974 and 1975. U.S. production in 1974 has been estimated to have been 363,000 kg (800,000 lb), an estimated 99% of which was exported--mainly to Latin America, Africa, and Asia (California State Department of Agriculture, 1976).

Environmental discharges of these manufacturers have led to kepone contamination of several water systems. The Allied and Life Sciences discharges entered the James River by way of Bailey's Creek. The kepone has been carried by the James River into Chesapeake Bay. The EPA estimates 100,000 lb of kepone is currently in the James River; about 10% of this kepone can be expected to move into the Chesapeake Bay (Pesticide Chemical News, Nov. 3, 1976). The Nease Chemical Company discharges wastes into Spring Creek in Pennsylvania. Spring Creek flows into Bald Eagle Creek, which in turn flows into the West Branch of the Susquehanna, the Susquehanna itself, and thence into the upper Chesapeake Bay. Kepone has been found in fish taken from Spring Creek and Chesapeake Bay (Pesticide Chemical News, Nov. 3, 1976). The Hooker Chemical Company discharges wastes into the Niagara River, which flows into Lake Ontario, and Lake Ontario empties into the St. Lawrence River. Kepone has been found in fish taken from Lake Ontario (Pesticide Chemical News, Nov. 3, 1976).

Registered producers of kepone products are listed in Table III-2. There are 26 federally registered producers and another 4 producers who are state applicants for federal registration. Possible environmental discharges of kepone for these companies are not known.

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Table III-2

LIST OF REGISTERED PRODUCERS OF KEPONE PRODUCTS (1976)

| Company | Address* |
|---|---|
| Action Product Corp. | North Miami, FL |
| Allied Chemical Co. | Morristown, NJ |
| Athena Corp. | Dallas, TX |
| Black Leaf Products Co. | Elgin, IL |
| Black Magic Co. | Jacksonville, FL |
| Boyle-Midway, Inc. | Cranford, NJ |
| Brown Chemical Specialty | San Antonio, TX |
| Clarence Boord and Sons, Inc. | Leon, IA |
| Common Sense Manufacturing Co., Inc. | Buffalo, NY |
| F. C. Sturtevant Co. | Cromwell, CT |
| Gaston Johnson Corp. | Long Island, NY |
| General Pest Service Co. | Los Angeles, CA |
| Grant Laboratories Div., Leisure Enterprises, Inc. | Oakland, CA |
| J. & F. Manufacturing Co. | Houston, TX |
| John Opitz, Inc. | Long Island, NY |
| Judd Ringer Corp. | Eden Prairie, MN |
| Lethelin Products Co., Inc. | Mount Vernon, NY |
| McCall Manufacturing Co. | Jasper, FL |
| Nott Manufacturing Co., Inc. | Pleasant Valley, NY |
| O. E. Linck Division, Walco Link Corp. | Clifton, NJ |
| Old 97 Company | Tampa, FL |
| Pearson and Company | Mobile, AL |
| Quinn Drug and Chemical Co. | Greenwood, MS |
| Trager Manufacturing Co., Inc. | Scranton, PA |
| Vinson Chemical Products Co. | Opalocks, FL |
| Winn Chemical Co., Inc. | Blountsville, AL |
| Asgrow Flcrida Co.† | Plant City, FL |
| Chem Pack Co.† | South Miami, FL |
| Landia Chemical Co.† | Lakeland, FL |
| Southern Mill Creek Products Co.† | Tampa, FL |

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*Corporate address and not necessarily manufacturing address.

†These four companies are state applicants for federal registration.

Source: EPA, Federal Register 41(59), (March 25, 1976).

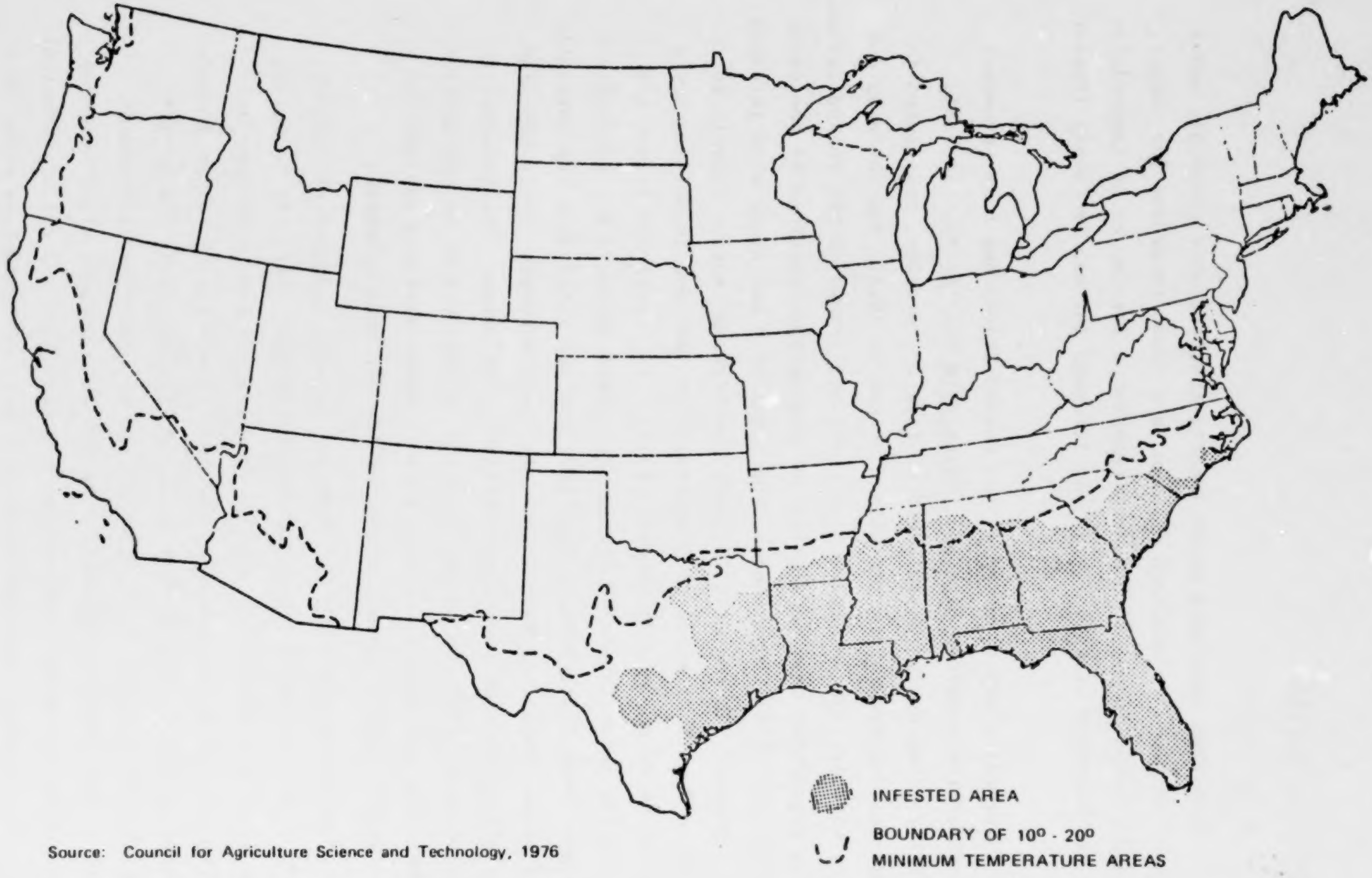
## C. Products and Uses

### 1. Mirex Uses

Mirex has been used as an insecticide; the same chemical, under the name of Dechlorane, has been offered as a flame retardant for rubber, paper, and plastic foam. It has been registered for use as an insecticide in nine southeastern states. It is not licensed for use in Canada (Forest, 1976).

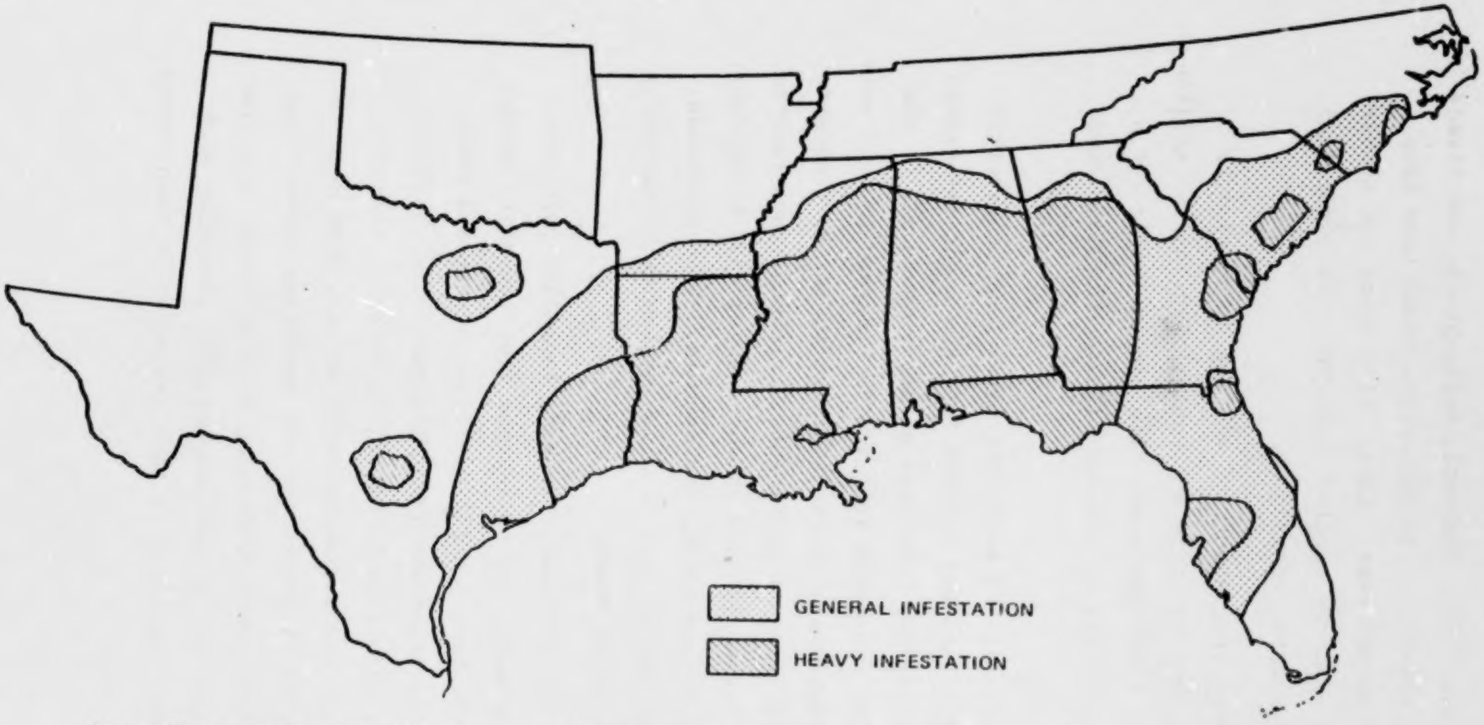
The major use of mirex in the United States has been to combat the spread of the imported fire ant, *Solenopsis saerissima*. The ant, which differs from native North American fire ant species, originated in Latin America and arrived in the United States in 1918. The ant does not appear to have any natural enemies to check its spread in the United States, where its population grew to significant nuisance proportions by the early 1950s (Shapley, 1971). Only about 2000 acres (0.8 hectares) were infested in 1932. However, in the next 15 years the fire ant spread rapidly to infest about 2 million acres (800 hectares) in 1947 and 26 million acres (10 million hectares) by 1959 (Norman, 1975). Fire ants now infest 135 to 150 million acres (55 to 60 million hectares) (Council for Agriculture Science and Technology, 1976). Figures III-1 and III-2 show the currently infested areas, including Mississippi, Alabama, Arkansas, North Carolina, South Carolina, Florida, Georgia, Louisiana, and Texas. The temperature boundary of -6 to 12°C (10 to 54°F), which is believed to be the barrier to further fire ant spread, is also shown. These barriers enclose the western coastal United States, which has not yet been infested.

The mirex bait used for fire ant control consists of corncob grit (85%), once refined soybean oil (approximately 15%), and technical mirex at 0.15% (Markin et al., 1972). The grit acts as a carrier and the soybean oil as an attractant. The grit is similar to coffee grounds in size and consistency, and when it is applied aerially, 170 or 320 granules will be found on each square meter of land--the differences representing two baits designated as 2x and 4x. Because of differences in formulations and application rates, either 1.7 or 3.5 g/a of technical mirex will be applied. Another version of bait designated as mirex 10:5, which is 70% less toxic than mirex 4x, has recently been formulated.


INFESTED AREA
BOUNDARY OF 10° - 20° MINIMUM TEMPERATURE AREAS

Source: Council for Agriculture Science and Technology, 1976

FIGURE III-1. FIRE ANT DISTRIBUTION, 1976


GENERAL INFESTATION
HEAVY INFESTATION

Note: The inner area enclosed by the heavier line shows where the ants are abundant enough that mirex is likely to be used.

Source: Marken, et al, 1972

FIGURE III-2. MAP SHOWING THE GENERAL AREA OF THE SOUTHEASTERN UNITED STATES INFESTED WITH THE IMPORTED FIRE ANT AS OF 1971

The bait may be applied by hand, jeep, tractors, helicopters, and fixed-wing aircraft on areas of infestation. Aerial applications have been repeated as many as three times per year. Table III-3 lists the number of acres treated and amounts of mirex applied from 1962, the first year of its use in controlling fire ants, to 1975.

It has been announced that about 6.5 million acres will be sprayed with mirex in spring 1977 for fire ant control; another 11 million acres have been scheduled for fall treatment. The program calls for a weakened mirex mixture to be applied by aircraft (Toxic Materials News, April 6, 1977).

Following its application to soil, the mirex bait is promptly picked up by the foraging fire ants and carried into the mound for transfer to other ants within the colony. The ants do not consume all of the mirex, some remains inside the discarded grit and is returned to soil surface. Among terrestrial communities, unused mirex grits may be consumed directly by insect scavengers (e.g., certain ants, crickets, wood roaches, and ground beetles). These scavengers are in turn preyed upon by spiders, reptiles, amphibians, insectivorous birds, and mammals. (Van Middelman et al., 1972). Some of these may in turn be eaten by humans or may serve as food for other animals eaten by humans.

The toxicant that has not been consumed, including bait that has not been picked up by the ants, may be leached from the bait, washed or occasionally blown directly into aquatic habitats, or carried there via food chains by immigrating organisms (Van Middleman et al., 1972). Because mirex is essentially insoluble in water, it probably becomes adsorbed onto organic detritus and sediments (Odum et al., 1969 and Maxwell et al., 1971). Species of freshwater and estuarine communities (e.g., crayfish, river shrimps, penalid shrimps, fiddler crabs, and blue crabs) are generally scavengers and accumulate mirex by consuming such detritus and sediments. These crustacea in turn are eaten by fish, birds, and mammals.

Table III-3

USE PATTERN OF THE INSECTICIDE
MIREX IN THE UNITED STATES FOR FIRE ANT CONTROL

| Year | Total Acres | Total Mirex (lb) |
|---|---|---|
| 1962 | 163,388 | 612 |
| 1963 | 1,523,469 | 5,710 |
| 1964 | 2,230,542 | 8,360 |
| 1965 | 3,599,003 | 13,488 |
| 1966 | 6,290,570 | 23,578 |
| 1967 | 10,417,187 | 39,044 |
| 1968 | 13,208,746 | 49,508 |
| 1969 | 11,557,182 | 43,508 |
| 1970 | 15,025,747 | 56,320 |
| 1971 | 11,609,907 | 43,510* |
| 1972 | 11,065,153 | 41,470* |
| 1973 | 14,184,017 | 53,160* |
| 1974 | 13,611,289 | 51,010* |
| 1975 (est) | 12,112,616 | 45,400* |

---

*Estimate based on acreage.

Source of 1962 to 1970 data: Markin et al. (1972).

Source of 1971 to 1975 acreage data: U.S. House of Representatives (1975).

In addition to the imported fire ant, several other species of locally important U.S. pests are effectively controlled by mirex applied as bait formulations. This includes the western harvester ant, Pogonomyrmex occidentalis, which infests millions of hectares of rangeland of the western states. Another is the Texas leaf-cutting ant, Atta texana, a serious pest for pine seedlings, hardwood trees, and cereal and forage crops in some areas of east Texas and west-central Louisiana. In heavily infested areas, the damage caused to buds, needles, and barks of all species of pine by this ant makes it impossible to establish natural reproduction. Seedling pines are often destroyed in such areas within a few days of planting (Van Middleman et al., 1972).

Beginning in 1970, mirex was also used in Hawaii to control populations of the big-headed ant, Pheidole megacephala, in pineapple fields (Bevenue et al., 1975). This ant has a symbiotic relationship with the pineapple mealybug, which is the transmission mechanism for mealybug wilt, a serious pineapple disease. Control of the ant population keeps the disease in check (Bevenue et al., 1975). In 1972 about 34,500 kg (76,000 lb) of bait was used (containing 220 lb of mirex) to treat 12,150 hectares (30,000 a).

The use of mirex in Hawaii was temporarily suspended in 1972 by EPA, but the suspension was later stayed on condition that a 1-year monitoring program approved by EPA be conducted. In 1973, the stay was continued, providing that a further mirex monitoring program was carried out (Bevenue et al., 1975).

In 1971, a mirex-based bait using canned fish as an attractant was introduced on a limited scale in California for control of yellow jackets (Keh et al., 1968; Wagner and Reirson, 1971).

Mirex has been found very effective against termites when soaked into the wood on which they feed (Esenther and Gray, 1968).

Under laboratory conditions, mirex has also been found quite toxic to honeybees (Anderson and Atkins, 1966). However, under actual field conditions when mirex-bait was aerially applied for control of the imported fire ant, mortality of adult worker bees was not observed, and significant residues of mirex were not found in bees or honey from hives in the treated area (Glancy et al., 1970).

Mirex has been tried as contact, ingested, or systemic insecticides against a number of insects. In most cases, it was found to be ineffective. Against several species, however, it was found fairly effective when incorporated into a bait or otherwise ingested, but no registration has been obtained for the use of mirex against these insects (USDA, 1972).

### 2. Kepone Uses

Kepone's main use has been as an insecticide--primarily for control of the banana root borer in many banana-producing countries. It has been used for this purpose in the U.S. territory of Puerto Rico. Directions call for surface applications at 6-month intervals or longer. The EPA Compendium of Registered Pesticides (CRP) (1973) lists the application dosage as 0.1 oz per plant or 2 lb/a. The CRP check list (EPA 1976a) lists a dosage of 8 lb/a. A tolerance of 0.01 ppm has been established in the United States for negligible residues of kepone in or on bananas (U.S. Code of Federal Regulations, 1976).

In the continental United States, kepone is primarily used as a roach and ant bait in houses and on lawns and gardens. Several registrations for kepone bait formulation, enclosed or not enclosed in traps, provide for general applications along baseboards, shelves, sills, or wherever ants may appear. Label directions do not always specify the limits of kepone bait that can be applied to a single room. Although labels warn against applying the insecticide in areas accessible to children or domestic animals, the directions also specify application where ants appear--obviously this could include areas that are clearly accessible (U.S. EPA, 1976a). The EPA (1976) lists 49 federal and 4 state products registered for this use. Presumably no more of these products will be sold after existing stockpiles of kepone have been exhausted or possibly after reregistration is denied. As of October 1976, there were 227 kg of kepone left in stockpiles in the United States (U.S. EPA, 1976d).

Kepone has been registered for use on nonbearing citrus to control the rust mite. Use was restricted to Florida and it could only be applied to the foliage of trees that would bear fruit within 1 year (U.S. EPA, 1973).

It has been used on tobacco to control the southern potato wireworm and the tobacco wireworm. The use was restricted to the southeastern United States where it was broadcast as a bait at a dosage of 1 lb/a in the spring before planting. Directions called for it to be incorporated into the top 6 in. of soil immediately after application (U.S. EPA, 1973).

A spray application was approved for use on commercial, field-grown gladioli for control of the corn earworm, fall earworm, and southern earworm. The spray mixture was 1 lb kepone per 100 gal of water per acre (U.S. EPA).

On February 1, 1968, all uses of kepone on Chinese cabbage, sweet corn, cucumbers, endive, lettuce, peppers, radishes, squash, sugarcane, and tomatoes were cancelled. All of these crops, except sugarcane, were treated by preplant applications of 2% kepone bait disked into the soil at the rate of 50 lb/a. Sugarcane was treated at the rate of 2 lb/a of kepone as a bait or 3-1/4 lb/a of kepone as a spray (U.S. EPA, 1976d).

### 3. Other Environmental Sources of Kepone

Kepone appears as a contaminant of mirex and as one of mirex's degradation products; hence, kepone should appear in the environment as a cocontaminant of mirex. The technical grade mirex taken from the Mississippi bait production plant contained kepone levels from 0.25 to 2.58 ppm (Pesticide Chemical News, August 4, 1976). Carlson et al. (1976) evaluated soil samples recovered after 12 years of mirex treatment and ant bait recovered 5 years after an aircraft crash. As much as 50% of the original mirex was recovered at levels of about 0.5 and 640 ppm, respectively. Kepone was present at levels of 0.02 ppm in soil and 10 ppm in the bait, or (i.e., it comprised as much as 10% of the recovered mirex).

Accidental exposures to both mirex and kepone are possible (particularly to children) because both materials have been incorporated into consumer products, (e.g., Dechlorane products and ant traps).

## IV ATMOSPHERIC ENVIRONMENTAL EXPOSURES TO MIREX AND KEPONE

### A. General

Atmospheric concentrations of mirex and kepone may have constituted an environmental problem near the primary product manufacturing areas. Because the primary products are no longer manufactured, the sources of these exposures and the exposures themselves no longer exist.

Workers who wore their contaminated clothing home are thought to have exposed their families as well. Except for the processing and application of mirex bait and Dechlorane, the sources of these exposures no longer exist.

Further environmental exposure may occur to people residing in or passing through areas in which mirex or kepone products have been applied. This exposure would include people residing or working in areas in which kepone bait or traps are being used for control of ants and roaches.

Some of these possible past and present atmospheric exposures are summarized in the following paragraphs. In general, it is concluded that future human environmental atmospheric exposures to mirex and kepone will be minimal.

### B. Mirex in the Atmosphere Near Manufacturing Facilities

No data on concentrations of mirex in the atmosphere have been found in the literature. Some atmospheric contamination may have been emitted from the primary manufacturing facilities, principally located near Niagara Falls, New York, and State College, Pennsylvania. Because the basic material is no longer manufactured in the United States, these exposures present no further problem.

With respect to air emissions near Hooker's Niagara Falls plant, Chambers (1976) states that no visible discharges were noted by the company or government personnel in their observations that were presumably made during the mirex grinding operations. The two automated dust collectors associated with the operations have listed manufacturer's removal efficiency of 99.9%.

## C. Kepone in the Atmosphere Near Manufacturing Facilities

The major, elevated atmospheric concentrations of kepone probably occurred in the residential areas near the primary product manufacturing sites. These areas have been located near Hopewell, Virginia; State College, Pennsylvania; and Niagara Falls, New York. No ambient data have been located for State College or Niagara Falls; however, samples were taken in the Hopewell area when the Life Sciences plant was producing kepone (Chemical Week, December 24, 1975).

Air monitoring stations in Hopewell were located at the Hopewell News building, 200 m (0.13 mi) south of the plant site and at the Hopewell airport 5.2 km (3.24 mi) to the east. Other sites were located in nearby communities at distances of from 12.5 to 25 km (7.8 to 15.6 mi). Hi-Vol samples collected at the station 200 m distant from March 1974 through April 1975, while the plant was in operation, were found to contain from 2 to 50 μg of kepone per cubic meter of air. Kepone concentrations varied, depending on the length of sample time, weather conditions, and date of collection. During this same sampling period, the percent of kepone in relation to the total suspended particulates ranged from less than 1 to more than 40%.

Hi-Vol air filters taken from the Hopewell airport, the Colonial Heights area, and the most distant site [South Richmond, which is approximately 25 km (16 mi) from the manufacturing plant] contained between 0.1 and 20 $ng/m^3$.

Occupational exposures in the Life Sciences plant measured by the State of Virginia in July 1975, showed airborne kepone concentrations of 3 $mg/m^3$ (Jaeger, 1976). The NIOSH-recommended workplace standard for kepone is 1 $\mu g/m^3$ (NIOSH, 1976).

Human respiration rates vary according to age, sex, type of work, degree of physical exertion and health of the individual; however, the variation is relatively small. An average adult is considered to respire 15 $m^3$/day and an average worker, 20 $m^3$/day--10 $m^3$ during working hours (Public Health Service, 1960).

Based on the environmental exposures at Hopewell, people residing near the Life Sciences plant would have inhaled 30 to 750 μg/day of kepone, whereas people residing about 25 km from the plant would have inhaled from 0.0015 to 0.3 μg/day of kepone. The occupational concentrations reported above appear to be excessive; however, they would result in an inhalation of 30 mg/working day of kepone. The NIOSH standard allows an occupational exposure of up to 10 μg/day.

## D. Human Atmospheric Exposure to Mirex from Product Use

Because mirex bait is only dispensed through the air when associated with relatively coarse corn cob grit particles that settle rapidly, amounts remaining airborne should be insignificant. With the high melting point and low vapor pressure of bait, volatilization on the ground should also be insignificant. This conclusion is enhanced by the fact that only 1.7 to 3.4 g of mirex are applied to each acre of treated land. If the entire amount of mirex present did volatize and remain in a layer of the atmosphere from ground level to 10 m elevation, the atmospheric concentration would be 42 to 84 μg/$m^3$. This, however, is a gross overexaggeration of concentrations that would actually be present.

A more accurate approximation can be made using the methods of Guckel et al. (1973). Using the evaporation rate of DDT (This rate is unavailable for mirex, but DDT has a similar vapor pressure.) assuming that the air is moving 50 L/hr at 20°C and that 1 g of mirex has a surface area of 5 $cm^2$, and using mirex's molecular weight of 546 gives an evaporation of 0.6552 g/24-hr/g of mirex. Using the same 10-m atmospheric layer and assuming that the air exchanges once every 24 hr results in atmospheric concentrations of $2.7 \times 10^{-2}$ to $5.5 \times 10^{-2}$ ng/$m^3$. People residing in areas with these concentrations would inhale 0.4 to 0.8 ng/day of mirex.

## E. Human Atmospheric Exposures to Kepone from Product Use

### 1. Ant and Roach Traps and Baits

Ant and roach bait and traps may be used indoors or outdoors. Indoor use may result in atmospheric contamination or contamination of food and water. Accidential exposures may also result, particularly to children, from tasting or eating the material contained in the trap or bait.

Each trap contains approximately 7.5 mg kepone at a concentration of 0.125% in bait. Indoor use calls for 2 or 3 teaspoons of paste, 2 or 3 tablespoons of granules, or 2 or 3 containers per infested room. Loose baits may be scattered or placed in piles (U.S. EPA, 1973). Hence, a single room may be baited with as many as 3 x 7.5 = 22.5 mg of kepone.

The methods of packaging the kepone bait has been defined by EPA (1976d) as "accessible" and "inaccessible." Inaccessible products include all enclosed traps made from metal or plastic, as well as metal stakes containing kepone baits that are hammered into the ground. Accessible products are those that can be removed from their containers, as well as foil- or cardboard-covered traps.

EPA estimated that as of August 1976, 538.8 lb of actual kepone was held by formulators of bait and traps (U.S. EPA, 1976d). This is enough to produce 27.5 million inaccessible traps and is estimated to be a 3-year supply. Thus, exposures to these traps and baits might be expected to persist for more than 3 more years as manufacturers' supplies are consumed and retail stocks are purchased.

### 2. Potential Atmospheric Exposure from Kepone Ant and Roach Traps

No known recorded data are available about atmospheric concentrations of kepone in rooms where kepone traps have been used. Therefore, in estimating the potential concentrations it is assumed that 3 traps are placed in a room 3 x 4 x 2.5 m (30 $m^3$). The very highest concentration would occur if all kepone in the traps entered the room atmosphere while no discharge of air from the room was permitted. The resulting atmospheric concentration would be 22.5/30 = 0.75 mg/m$^3$. This concentration is unreasonably high because of the low volatilization rate of kepone and because of circulation of the air.

The data submitted to EPA by Lethelin Products Company, though not relevant to household exposure estimation, do provide a measure of the vapor concentrations attainable under maximum conditions (a factory formulating bait from powdered kepone). For this case, the maximum concentration is 1 μg/m$^3$ for kepone in dust-free air (U.S. EPA, 1976c).

The actual evaporation rate of chemicals is difficult to measure, and quantitative data are rare. An experimental method has been devised (Guckel et al., 1973), however, to measure the evaporation rate of pure pesticides from a thin film. The technique involves observing the loss in weight of a pesticide at a specified temperature and air flow by using a very sensitive balance. Kepone was not measured, but data are given for DDT, another chlorinated hydrocarbon with a vapor pressure in the same range as that of kepone (U.S. EPA, 1976c).

For air at 20°C moving at 50 L/hr, the evaporation rate of DDT was $<0.01 \times 10^{-9}$ moles/cm$^2$/hr. Applying this limiting value to kepone gives

$$0.01 \times 10^{-9} \text{ moles/cm}^2\text{/hr} \times 490 \text{ (molecular weight of kepone)}$$
$$= 0.0049 \ \mu\text{g/cm}^2\text{/hr of kepone.}$$

The surface of a kepone trap is approximately 20 cm$^2$, giving 0.1 μg/hr or 2.4 μg/day evaporation from a trap under these conditions. For three traps in a 30-m$^3$ room, the concentration is 2.4 x 3/30 = 0.24 μg/m$^3$. However, this estimated evaporation is grossly exaggerated because the air inside the kepone trap is not moving and because the concentration of kepone (and thus the exposed surface) is only 0.125% in the bait. By assuming that the rate of evaporation is proportional to concentration a more realistic concentration would be less than 0.00125 x 0.24 = 0.3 ng/m$^3$ (U.S. EPA, 1976c). This assumes that all the air inside the room would recirculate daily.

If it is assumed that a person inhales 15 $m^3$/24 hr of air and that he spends all 24 hr in the room, daily exposure (inhalation) would be approximately 4.5 ng/24-hr day, with an upper limit of 3.6 μg/p day.

### 3. Potential Atmospheric Exposure from "Accessible" Kepone Bait

Unenclosed kepone bait is formulated in a variety of matrices, such as paste, jelly, bread crumbs, and corn cob grit; the usual concentration is 0.125%, the same as for the bait in the traps. An assessment of inhalation exposure from the use of loose bait, using assumptions similar to those for the enclosed case, requires an estimate of the volatilization rate of kepone and thus of the surface area of the bait. The surface area for one can of bait is estimated as 1800 $cm^2$ (U.S. EPA, 1976c).

Using the kepone evaporation rate of 0.0049 μg/$cm^2$/hr given above, assuming the air in the room (30 $m^3$) is replaced completely once every 24 hr, and assuming that 0.125% of the surface area is kepone result in a calculated atmospheric concentration of

$0.0049 \times 1800 \times 0.00125/30 = 9\ ng/m^3$.

Note that at the assumed evaporation rate it would take 166 days to evaporate all the kepone from the bait (U.S. EPA, 1976c).

Again, assuming that an adult inhales 15 $m^3$ of air per day and that he remains in the room for 24 hr per day, his exposure would be

$15 \times 9 = 135$ ng/day.

Additional atmospheric exposures may occur for both accessible and inaccessible ant and roach traps by the bait being eaten or carried off by the insect. The insect could then die or drop the bait into a room where it would be available for suspension into the atmosphere as a dust particle or the kepone could vaporize into the room's atmosphere. If it is assumed that one-half of the material for three traps in a room is so exposed, a possible 11.25 mg of kepone are released into the room. A 30-$m^3$ room could have a maximum possible kepone concentration of 0.38 mg/$m^3$ if all the material entered the room's atmosphere at one time. This, of course, is a gross overestimate because not all the material would enter the room's atmosphere at one time, because the air in the room would be replaced by outside air, and because some of the kepone would be removed through housekeeping. The maximum possible kepone concentration for this exposure route could easily overestimate the actual concentration by a factor of $10^3$ to $10^6$ or more.

### 4. Accidental Exposures to Kepone from Ant and Roach Traps and Bait

According to the EPA (U.S. EPA, 1976a), 46 cases of human kepone poisoning have been reported (primarily children). In only one case was the causitive agent confirmed to be kepone. No deaths were attributed to acute poisoning. EPA (1976d) lists 52 reported incidents since 1971.

Data from the Pesticide Episode Report System (PERS) show an average of 12.5 cases per year involving young children and kepone products (U.S. EPA, 1976d). In almost all episodes involving traps, the children were found chewing the can without any indication that they had ingested the contents. If it is assumed that some do ingest the contents and that the can is partially full, they might eat 5 mg of kepone or about 6.7 ppm in their diet for that day. Because only a small fraction of the total number of such actual cases are probably reported, this fraction is assumed to be 1%, with the implication that 1250 such cases might occur each year.

The possibility that a child, or anyone, might be exposed to kepone dissolved by water or in deposits on dishes, pans, and eating utensils was judged to be remote (U.S. EPA, 1976d).

### 5. At-Risk Population for Atmospheric Mirex and Kepone

At-Risk Populations for Kepone Baits and Traps--It has been estimated that the remaining stocks of kepone would be sufficient to make a 3-year supply of traps and baits. The supply could be used to make 27.5 million unaccessible traps or if used half-and-half it could make 13.8 million inaccessible traps and 430,000 accessible products (U.S. EPA, 1976c).

Using the half-and-half production figure and assuming three traps per room leads to an estimate of 1.5 million rooms per year baited with inaccessible traps and 50,000 rooms per year baited with accessible traps. Using an estimate of 4 people per room application leads to an estimate of 6 to 12 million people exposed per year. These estimates assume that all the material would be used indoors and they are an upper limit of the number potentially exposed.

At-Risk Population for Mirex Fire Ant Application--Table III-3 indicates that the average number of acres treated per year in rural areas for fire ant control was 10 to 14 million from 1967 to 1975. Using the U.S. rural population density of 15 people/sq mi gives an estimated 230,000 to 330,000 people exposures per year. Because some of the areas received multiple treatments, some individuals would have received multiple exposures.

At-Risk Populations for Mirex and Kepone Manufacturing--Manufacturing exposures no longer exist because the basic mirex and kepone materials are no longer manufactured. Using a radius of 8 km (5 mi) from the plants to characterize past exposed populations, it is estimated that there were approximately 25,000 people at risk in the vicinity of Hopewell, 30,000 people at risk near State College, and 90,000 at risk near Niagara Falls. These 155,000 people would have been at-risk to atmospheric kepone at some time, and the 130,000 people in State College and Niagara Falls would also have had potential mirex exposure. Environmental kepone exposures may also have occurred near the Allied formulation plant in Baltimore; if so, they would predate 1960 and were probably minimal in comparison with the latter Life Sciences emissions in Hopewell.

Additional exposures may have occurred near the various consumer product manufacturing plants. But because of the processes employed and amounts of materials involved, these were probably minimal.

# V MIREX AND KEPONE IN DRINKING WATER SUPPLIES

## A. General

Mirex and kepone concentrations in drinking water have not been found to constitute a significant human exposure. Both chemicals are relatively insoluble in water and both are rapidly adsorbed onto sediments. The only measurable human exposures would probably occur from ingesting kepone and mirex on sediments resuspended during periods of extreme turbidity, when little filtration occurred.

## B. Mirex in Water

Because mirex has a relatively low solubility, if present, it would be expedted to be found at levels less than fractional parts per billion. This occurrence is below the detection level for most analytical methods. Because of mirex's being found in Lake Ontario sediments, all New York state water supplies receiving their water in the Great Lakes Basin were tested for mirex and some were tested for kepone from September to October 1976. These water supplies are listed in Table V-1, and include those taking their water from Lake Erie, the Niagara River, Lake Ontario, and the St. Lawrence River. Nothing was found at or above the 0.01 ppb detection level (Syrotynski, 1977). Because increased turbidity due to spring turnover might result in detectable levels, New York State plans to conduct a spring research program to measure the sediment-water interface.

Analyses of more than 50 water samples routinely collected after mirex treatment in the Southwest have failed to detect it at the 0.1 ppb level. Better methods of monitoring have found mirex in the range of <1 ppt (Markin, 1972). However, the mirex was not detected in the water itself. but in the suspended matter filtered from it. Borthwick et al. (1973) report a similar lack of success in detecting mirex in estuarine samples in South Carolina after aerial application of mirex bait. Alley (1973) also states that mirex has not been detected in natural waters by analytical techniques sensitive to 0.01 ppb.

## Table V-1

## NEW YORK PUBLIC WATER SUPPLY SYSTEMS IN THE GREAT LAKES BASIN TESTED FOR MIREX

### Lake Erie

Dunkirk, Wanakah, Erie County Water Authority, Buffalo City

### Niagara River

Erie County Water Authority, Grand Island Water District #2, Tonawanda, Lockport City, Niagara Falls City,

### Lake Ontario

Niagara County Water District (at mouth of River), Lyndonville Village, Hilton Village, Monroe County Water Authority, Rochester City (half comes from upland to south), Ontario Water District (Wayne County), Williamson Water District, Sodus Point, Wolcott Village, Oswego City, Onondaga County Water District, Syracuse City, Chaumont (Chaumont Bay)

### St. Lawrence

Cape Vincent, Alexandria Bay, Clayton, Morristown, Massena

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Note: Intakes are shared by the following systems: Monroe County and Rochester, Onondaga County, and Syracuse.

Source: Syrotynski (1977).

No detectable levels of mirex were found in Spring Creek, Pennsylvania, downstream from the Nease chemical plant (Clista, 1977).

Mirex concentrations in sediments and biota are monitored in the Hawaiian pineapple growing areas. Although water is not monitored, no mirex was detected in sediments at the 3-ppb limit of detectability (Johnson et al., 1976).

## C. Kepone in Water

As indicated previously, kepone has been primarily used in tropical regions outside of the United States to control banana root borers. The principal U.S. uses have been to control ants and roaches around homes and for wireworm control in the southeastern United States. According to one EPA estimate, only 0.8% of the U.S. kepone production has been used in the United States [ i.e., on the order of 900 kg/yr (2000 lb/yr)]. Most of this amount would be contained in traps or dispersed indoors or near homes. Thus, water contamination from use should be minimal.

The major contamination of water bodies would come from manufacturing discharges centered at Hopewell, Virginia; State College, Pennsylvania; and Niagara Falls, New York. Lesser discharges may also have occurred at secondary product manufacturers centered at a number of locations throughout the United States.

Other sources of kepone in the water might result from degradation of environmental concentrations of mirex because kepone has been reported as a cocontaminant of mirex (Pesticide Chemical News, August 4, 1976).

Most sampling of kepone in water has focused on the James River and Chesapeake Bay, with other sampling in Spring Creek, Pennsylvania, and Lake Ontario. The Pesticide Chemical News (August 11, 1976) reports that in water samples taken from Spring Creek, downstream from the Nease chemical plant, no detectable levels of kepone were found. However, Ted Clista of the Pennsylvania Department of Environmental Resources indicates finding concentrations of 0.02 to 0.09 ppm kepone in Spring Creek. No kepone was reported found in analyzed New York State water supplies that take their water from the Great Lakes Basin (Syrotynski, 1977).

Tap water taken from the Hopewell, Virginia, area contained no detectable kepone at the time of sampling. Ice samples from an ice plant across the street from the Life Science Products Company manufacturing site contained from 0.1 to 10 ppb of kepone (Chemical Week, December 2, 1975). Similar concentrations were determined in the discharge water from the kepone manufacturing site. Samples from the James River ranged from 0.1 to 4 ppb (Chemical Week, December 24, 1975). Other field data revealed concentrations of 0.13 to 0.14 ppb of kepone in James River water near Skiffs Creek (Toxic Materials News, December 27, 1976). The levels of kepone found were undetectable (< 50 ppt) in the York River (the next major river north of the James, which also discharges into the Chesapeake Bay). In the Appomattox River (upstream from Hopewell), kepone was detected at 0.1 ppb.

## D. Human Consumption of Mirex and Kepone from Drinking Water

Human water consumption rates vary according to age, sex, work, health conditions, and temperature. The average adult is considered to consume 1.5 L of water daily as liquid (Public Health Service, 1960). Because detectable levels of mirex have not been recorded in drinking water supplies, it must be assumed that the human exposure is low (less than $0.1 \text{ ppb} \times 1.5 \text{ L/day} = 0.15 \times 10^{-9} \text{ L/day}$). Hence, the mirex consumption would be less than 0.15 μg/day. Kepone concentrations of 0.1 to 10 ppb may be present in some water supplies. This would yield a daily human consumption of about 0.15 to 15 μg/day for water supplies that might be contaminated.

These consumption estimates are highly speculative. No data have shown positive mirex or kepone concentrations in tap water. Municipal water filtration systems remove most of the sediments and, hence, most of the mirex and kepone that might be present.

## E. At-Risk Population to Kepone in Drinking Water

Hopewell is the only municipality taking its drinking water from the lower James River between Hopewell and the Chesapeake Bay. The Hopewell water treatment system is frequently monitored to ensure that whatever kepone is present is removed. No detectable concentrations have been reported in the finished water. Therefore, the at-risk populations to kepone-contaminated drinking waters would at most be those few people who take their water directly from the river.

## VI POTENTIAL HUMAN MIREX AND KEPONE EXPOSURES FROM SMOKING

No data have been found to indicate the presence of mirex or kepone in tobacco. Both chemicals should be found in the soils of certain tobacco fields because mirex has been used in the Southeast to control imported fire ants and because kepone has been used on tobacco to control the southern potato wireworm and the tobacco wireworm.

Studies by De La Cruz and Rajanna (1975), Alley (1973), and Markin et al. (1972) indicate that plants can take up mirex if it is present in the soils. The concentration in the plant was found to depend on the concentration in the soil, the type of soil, the plant species, and the parts of the plant (i.e., roots, leaves, stem, etc.) in which it was found. The concentration of mirex in the soil of areas treated for imported fire ant control depends on the time since last treatment. The soil concentrations would probably be several parts per billion immediately after application, decreasing to fractional parts per billion thereafter (Van Middelman et al., 1972; Markin et al., 1972; and Spence and Markin, 1974). Considering these data and the plant uptake data, one might expect concentrations in tobacco from selected locations in the order of parts per trillion.*

To find if the mirex postulated in tobacco could be transmitted to the lungs when smoking, Atallah and Dorough (1975) devised a quantitative smoking system for collecting mainstream smoke or for delivering smoke to the lungs of rats via the trachea. Cigarettes were impregnated with five $^{14}C$-labeled insecticides (including mirex) and then tested. Approximately 23% of the added mirex radiocarbon was recovered unaltered in the mainstream smoke. Mirex was found to be the most stable compound tested, with approximately 70% of the recovered radiocarbon remaining as the original product. When mirex was inhaled by rats using the trachea smoking system, 47% was exhaled, 36% was found in the rats' lungs, 11% in their bloods, and 1% in their hearts; about 5% was lost in recovery process. These data indicate not only that mirex would survive the smoking process but also that mirex entering the lungs can be taken into the lungs, blood, and heart and, hence, into other organs and tissue.

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*A concentration of 1 ppt might be assumed. See Section VII-A-1 for a discussion concerning this assumed concentration.

Assuming that 23% of the mirex in a cigarette is taken into the lungs, that an average cigarette's weight is 0.9 g, and that the concentration of mirex in the cigarette is 1 ppt, human exposure from one cigarette would be $2 \times 10^{-12}$ g. A telephone survey of adults conducted by HEW (1970) between 1969 and 1970 indicated that approximately 42% of the males and 30% of the females smoke cigarettes. Current male smokers average 22 cigarettes per day and females 18 per day. The estimated average daily mirex exposure would thus be 4.4 pg for male smokers and 3.6 pg for female smokers. The consumption would, of course, be higher for heavy smokers.

These estimates are speculative, however, because it is not known whether mirex or kepone are still present in tobacco field soils; whether tobacco will take up mirex or kepone; and what concentration of the two chemicals might actually be present in tobacco.

## VII MIREX AND KEPONE CONCENTRATIONS IN FOODS

### A. Mirex in Foods

### 1. General

The established tolerances for mirex in foods are 0.1 ppm in fat of meat from cattle, goats, hogs, horses, poultry, and sheep; 0.1 ppm in eggs; 0.1 ppm in milk fat; and 0.01 ppm in all agricultural commodities exclusive of eggs, milk fat, and animal fat (EPA CPR, May 31, 1969). The 0.1-ppm limit has also been applied to finfish.

Foods that might be contaminated by mirex include those grown or raised in areas where mirex has been manufactured or applied for pest control. These areas are the southeastern states where mirex has been used to control fire ants and Hawaii where mirex has been used to control mealybug wilt disease on pineapples. Product manufacturing has contaminated seafood in Lake Ontario, the St. Lawrence River, and Spring Creek.

Animals that produce food can become contaminated with mirex as a result of their ingesting plant and animal materials and waters that have been mirex-contaminated. Mirex, like many other chlorinated organic compounds, is only slightly soluble in water but extremely soluble in fats and oils. Because of this, it will usually migrate to portions of the environment that are high in fats and oils. Because most biological organisms contain fats and oils, it tends over time to accumulate in them at much higher levels than exist in the environment (DEC, 1976d). This bioaccumulation and the nonbiodegradability of the compound are the properties that make it of special concern to ecological and public health specialists.

Bond et al. (1975) fed mirex-contaminated food to cattle to monitor the accumulation of mirex residues in the milk and fatty tissue of the cows and in the calves receiving milk from these cows. Residues of 0.08 ppm of mirex or less were found in the milk and less than 2.52 ppm in the fat samples.

Aquatic, food-producing species can become contaminated with mirex either through directly consuming contaminated sediments or water, or through food chain build-up. These contaminations have been found to be particularly problematic in Lake Ontario, the St. Lawrence River, Spring Creek, and to a lesser extent the southeastern United States.

Mirex contamination of food plants can result from aerial application of the pesticide on the plants and from root uptake of concentrations in the soils.

Preliminary work on a number of biological samples has shown that plants can contain extremely low concentrations of mirex (Alley, 1973). Markin et al. (1972) reported that bahiagrass contained 0.0003 to 0.017 ppm residues when grown in soils containing 0.001 to 0.002 ppm mirex. De La Cruz and Rajanna (1975) studied mirex uptake in soybeans, garden beans, sorghum, and wheat seedlings grown in sand and soil substrates containing 0.3 to 3.5 ppm mirex. The seedlings were found to contain between 0.01 to 1.71 ppm mirex (see Tables VII-1 and VII-2). Generally, the mirex concentrations for seedlings grown in soil were higher than those grown in sand. As might be expected, higher concentrations were found in plants grown in the soils having the higher mirex concentrations.

At the standard application rate, approximately 1.7 g/a of active mirex is applied. It has been calculated that this is equivalent to approximately 4 ppb (Van Middleman et al., 1972) or 5 ppb (Markin et al., 1972) in a standard 3-in. soil sample. Concentrations in treated soils have been reported as 0.1 to 10 ppb (Van Middleman et al., 1972), 0.7 to 2.5 ppb (Markin et al., 1972), and 0.2 to 10.4 ppb (Spence and Markin, 1974). Based on an extrapolation of the plant uptake data reported by De La Cruz and Rajanna (1975) and Markin et al., (1972), plants grown in these soils might be expected to contain mirex concentrations on the order of 0.2 ppt to 2 ppb, with a midvalue of about 1 ppt. These concentrations will depend on, among other factors, the time since the last mirex application; consequently, current vegetation concentrations may be less than 1 ppt for most regions.

## Table VII-1

## CONCENTRATIONS OF MIREX RESIDUES (PPM DRY WEIGHT) DETECTED BY GLC IN DIFFERENT PARTS OF 4-WEEK OLD CROP SEEDLINGS GROWN IN FIELD SOIL

| Plant Parts | Concentration of Mirex in the Experimental Field Soil (ppm) | | |
|---|---|---|---|
| | 3.50 | 0.80 | 0.30 |
| Garden Beans | | | |
| Growing tip | 0.12 | 0.06 | 0.02 |
| Leaves | 0.20 | 0.11 | 0.01 |
| Upper half stem | 0.31 | 0.22 | 0.10 |
| Lower half stem | 0.63 | 0.25 | 0.02 |
| Root | 1.18 | 0.49 | 0.21 |
| Soybean | | | |
| Growing tip | 0.09 | 0.06 | 0.01 |
| Leaves | 0.21 | 0.12 | 0.10 |
| Upper helf stem | 0.35 | 0.18 | 0.11 |
| Lower half stem | 0.76 | 0.27 | 0.12 |
| Root | 1.25 | 0.49 | 0.17 |
| Sorghum | | | |
| Leaves | 0.22 | 0.20 | 0.11 |
| Stem | 0.51 | 0.31 | 0.17 |
| Root | 0.81 | 0.44 | 0.20 |
| Wheat | | | |
| Leaves | 0.17 | 0.18 | 0.09 |
| Stem | 0.56 | 0.20 | 0.20 |
| Root | 1.17 | 0.27 | 0.23 |

Source: De La Cruz and Rajanna (1975).

Table VII-2

CONCENTRATIONS OF MIREX RESIDUES (PPM DRY WEIGHT) DETECTED BY GLC IN DIFFERENT PARTS OF 4-WEEK OLD CROP SEEDLINGS GROWN IN LOAMY SAND

| | Concentration of Mirex in the Experimental Loamy Sand (ppm) | | |
|---|---|---|---|
| Plant Parts | 3.40 | 0.80 | 0.31 |
| Garden Beans | | | |
| Growing tip | 0.27 | 0.09 | 0.04 |
| Leaves | 0.40 | 0.19 | 0.01 |
| Upper half stem | 0.31 | 0.28 | 0.17 |
| Lower half stem | 0.79 | 0.38 | 0.20 |
| Root | 1.68 | 0.69 | 0.23 |
| Soybean | | | |
| Growing tip | 0.31 | 0.08 | 0.05 |
| Leaves | 0.36 | 0.18 | 0.03 |
| Upper half stem | 0.73 | 0.29 | 0.13 |
| Lower half stem | 0.92 | 0.31 | 0.27 |
| Root | 1.47 | 0.49 | 0.32 |
| Sorghum | | | |
| Leaves | 0.40 | 0.33 | 0.18 |
| Stem | 1.60 | 0.46 | 0.21 |
| Root | 1.71 | 0.67 | 0.28 |
| Wheat | | | |
| Leaves | 0.21 | 0.19 | 0.04 |
| Stem | 0.95 | 0.32 | 0.21 |
| Root | 1.33 | 0.55 | 0.36 |

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Source: De La Cruz and Rajanna (1975).

Lane (1973) conducted laboratory experimentation to determine if food processing degrades mirex in food. Tissue samples and eggs contaminated with mirex were obtained from crawfish and mallard ducks. Under heat treatment, no significant difference was found in the mirex residues in the control and processed samples. The irradiation of crawfish tissues with ultraviolet light for 12 and 24 hr showed no significant difference in the means of the control or treated samples. Photolysis and gamma irradiation of eggs, however, significantly degraded the mirex content.

## 2. Mirex in Foods Grown in the Southeastern United States

Mirex bait has been applied in seven southeastern states to control the imported fire ant. The amount applied to any given location was slight (1.7 to 3.4 g/a per application, depending on formulation); however, due to mirex's persistence in the environment, measurable concentrations are expected in the soils and sediments of these areas for many years to come (mirex's environmental half-life may be on the order of a decade or more).

Ford et al. (1973) analyzed samples of beef fat to determine concentrations of mirex and other chlorinated pesticide residues. Samples were obtained from the Southeast and from other areas that had not been treated for imported fire ant control. Residues of mirex were found in 67 of the 77 (87%) fat samples tested from the Southeast. Positive concentrations ranged from 0.001 ppm (the lowest level of detection) to 0.125 ppm, with an average value of 0.026 ppm. Only one sample, 0.125 ppm, was in excess of the established tolerance level of 0.1 ppm in the fat of beef cattle. Analysis of other tissues taken from the same cattle showed no residues or minimal residues.

Beef samples taken from outside the treated areas showed no mirex residues. The absence of mirex in samples from untreated areas, although it does not provide absolute proof that the residues found in samples resulted from the insecticide application of the treated areas, does strongly indicate that this is the case (Ford et al., 1973).

In obtaining a registration and tolerance level for mirex, Allied Chemical Company monitored whole milk and milk fat from a herd of cows grazing on a pasture treated with a single application of bait. They reported 0.002 to 0.007 ppm in whole milk and 0.02 to 0.13 ppm in milk fat (Hawthorne et al., 1974). Because the same residue levels were found in pretreatment and untreated check animals, Hawthorne et al. (1974a) initiated another study: A total of 66 samples was obtained from 5 states, including 6 control samples obtained from untreated areas. The treated areas had received two to five mirex applications. Of the 60 samples analyzed from these areas, no mirex residues at the 0.3-ppb level of detection were found; however, at least 26 of the samples came from areas that had received their last mirex treatment a year or more before collection. Another 26 of the samples came from areas that had been treated at least 6 months before sampling. The authors conclude that milk cattle must be ingesting small amounts of mirex but not enough to show up in milk at residue levels above 0.3 ppb.

The FDA conducted a 1976 survey to measure the mirex concentrations of fishery products from seven south Atlantic-Gulf Coast states (FDA, 1977) that had been treated with mirex to control imported fire ants. The data obtained from 132 samples of finfish, shellfish, and crustacea are summarized on a regional basis in Table VII-3 and on a species basis in Table VII-4. None of the shellfish or crustacea surveyed showed detectable mirex. For finfish, however, all surveys except those from Texas contained some samples with detectable mirex. The average mirex in finfish by states was:

- Alabama, 0.029 ppm
- Arkansas, 0.021 ppm
- Georgia, none sampled
- Louisiana, 0.015 ppm
- South Carolina, none sampled
- Mississippi, 0.002 ppm
- Texas, none detected
- Florida, none sampled.

## Table VII-3

## MIREX IN SOUTHEASTERN U.S. FISH
(ppm)

| State (Region) | Finfish | | Shellfish | | Crustacea | |
|---|---|---|---|---|---|---|
| | Number | Average | Number | Average | Number | Average |
| **Alabama** | | | | | | |
| Northern | 8 | 0.035 | — | | — | |
| Southern | —[†] | | 12 | ND[*] | — | |
| Eastern | 4 | 0.018 | — | | — | |
| State | 12 | 0.029 | 12 | ND | | |
| **Arkansas** | | | | | | |
| Southern | 3 | 0.083 | — | | — | |
| Central | 9 | ND | — | | — | |
| State | 12 | 0.021 | — | | — | |
| **Florida** | | | | | | |
| Northern | — | | — | | 1 | ND |
| State | — | | — | | 1 | ND |
| **Georgia** | | | | | | |
| Eastern | — | | — | | 11 | ND |
| State | — | | — | | 11 | ND |
| **Louisiana** | | | | | | |
| Northern | 1 | 0.022 | — | | — | |
| Southern | — | | 12 | ND | 12 | ND |
| Central | 11 | 0.014 | — | | — | |
| State | 12 | 0.015 | 12 | ND | 12 | ND |
| **Mississippi** | | | | | | |
| Southern | — | | — | | 12 | ND |
| Central | 12 | 0.002 | — | | — | |
| State | 12 | 0.002 | — | | 12 | ND |
| **South Carolina** | | | | | | |
| Eastern | — | | — | | 12 | ND |
| State | — | | — | | 12 | ND |
| **Texas** | | | | | | |
| Northern | 6 | ND | — | | — | |
| Southern | 6 | ND | — | | — | |
| State | 12 | ND | — | | — | |

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[*] ND - None Detected.

[†] No samples taken.

Source: FDA (1977).

Table VII-4

SUMMARY OF FY77 MIREX COMPLIANCE EVALUATION PROGRAM FOR SOUTH ATLANTIC-GULF COAST FISHERY PRODUCTS BY SPECIES AND STATE

| State (Species) | Sample Size | Average | Minimum | Maximum |
|---|---|---|---|---|
| Alabama | | | | |
| Buffalo Fish | 4 | 0.040 | 0.030 | 0.070 |
| Carp | 1 | 0.010 | --† | -- |
| Catfish | 7 | 0.020 | Trace | 0.060 |
| Oysters | 12 | ND* | -- | -- |
| Arkansas | | | | |
| Buffalo Fish | 6 | Trace | ND | 0.020 |
| Carp | 1 | 0.150 | -- | -- |
| Catfish | 2 | ND | -- | -- |
| Drum Fish | 2 | ND | -- | -- |
| Garfish | 1 | ND | -- | -- |
| Florida | | | | |
| Crab | 1 | ND | -- | -- |
| Georgia | | | | |
| Crab | 5 | ND | -- | -- |
| Shrimp | 6 | ND | -- | -- |
| Louisiana | | | | |
| Buffalo Fish | 3 | 0.004 | Trace | 0.007 |
| Carp | 3 | 0.025 | ND | 0.066 |
| Catfish | 3 | 0.010 | ND | 0.022 |
| Gar | 1 | ND | -- | -- |
| Gasper (gou) | 2 | 0.029 | 0.008 | 0.050 |
| Oyster | 12 | ND | -- | -- |
| Crab | 6 | ND | -- | -- |
| Shrimp | 6 | ND | -- | -- |
| Mississippi | | | | |
| Buffalo Fish | 5 | ND | -- | -- |
| Carp | 1 | ND | -- | -- |
| Catfish | 6 | Trace | ND | 0.010 |
| Crab | 2 | ND | -- | -- |
| Shrimp | 10 | ND | -- | -- |
| South Carolina | | | | |
| Crab | 6 | ND | -- | -- |
| Shrimp | 6 | ND | -- | -- |
| Texas | | | | |
| Drum | 2 | ND | -- | -- |
| Flounder | 1 | ND | -- | -- |
| Redfish | 5 | ND | -- | -- |
| Trout | 4 | ND | -- | -- |

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*ND - None Detected.

†Range not applicable.

Source: FDA (1977).

The highest concentration fround was 0.15 ppm in an Arkansas carp. The breakdown by geographic areas (Table VII-3) within the states shows some variation in mirex levels in finfish from different areas. A further analysis of these findings indicates a positive correlation between 1976 mirex treated areas and positive mirex concentrations (FDA, 1977).

In the imported fire ant eradication program, mirex was aerially applied to coastal areas near Charleston, South Carolina. Results of field studies conducted to monitor the movement and accumulation of the mirex applied in the estuarine system were reported by Borthwick, et al.,(1973). Background and periodic posttreatment samples collected from 1969 to 1971 of water, bottom sediments, shrimp, crabs, fish, and estuary-dependent birds and mammals were analyzed for mirex using electron-capture gas chromatography.

The data revealed that (1) mirex was translocated from treated lands and high marshes to estuarine biota--all animal classes sampled contained mirex--and (2) higher biological concentrations of mirex occurred in predators such as racoons and birds. Mirex residue ranges for respective sample categories were: water, <0.01 ppm; sediments, 0 to 0.07 ppm; crabs, 0 to 0.60 ppm; finfish, 0 to 0.82 ppm; shrimp, 0 to 1.3 ppm; mammals, 0 to 4.4 ppm; and birds 0 to 17.0 ppm.

In a following study (Borthwick, et al., 1974), estuarine sediments, crabs, shrimps, and finfish were collected in June 1972 at 11 stations. The collection took place 2 years after aerial applications of mirex bait for control of imported fire ants in coastal areas near Charleston. Mirex was present in three species of fish (white catfish, 0.021 ppm; bluegill, 0.047 ppm; carp, 0.12 ppm) and blue crabs (0.026 ppm) at two freshwater stations. However, mirex was not detected in 36 animal samples, most of which were taken from nine saline stations in the estuaries after a period of restricted use of the pesticide. Analysis of bottom sediment samples at all stations detected no mirex. The test detection level of 0.01 ppm indicates that mirex in crabs, shrimp, and finfish diminished in the 18 to 24 months between the two studies.

Wild catfish from areas receiving blanket application of mirex bait have shown residues of 0.008 to 2.59 ppm. The higher concentrations were found within 48 hours of application, and the lower concentrations were found 2 years after application (Hawthorne et al., 1974b). Hawthorne et al. (1974b) also collected samples of 50 commercially raised catfish in the southeast; 25 came from areas that had been treated with mirex and 25 from areas that had not been treated. Mirex was found in none of the 50 samples at the 0.01 ppm detection level.

Other programs have monitored the mirex concentrations in wildlife in the southeastern United States. Many of the target organisms monitored are not used directly as human food but may indirectly enter the human food chain or indicate concentrations of other foods consumed by humans. For example, Oklendorf et al. (1974) collected eggs of anhingas, herons, and ibises during 1972 at coastal and inland locations from Florida to New Jersey. Of 209 eggs tested, 17.7% were found to contain mirex. The highest levels occurred in samples from coastal Georgia, inland South Carolina, and inland Florida. Mirex concentrations as high as 2.9 ppm were detected.

In a study reported by Markin et al. (1974), 77 samples, each composed of oysters, crabs, shrimp, fish and fish products, were collected from 7 coastal locations during 1971 within the area where mirex was used and from 2 check locations outside the treatment areas. The study showed that mirex occurred in only 9 of the 77 samples (0.005 to 0.024 ppm range), all of which come from near Savannah, Georgia. This area of Georgia had been treated in 1967, 1969, and 1970.

Markin et al. (1972b) sampled wild populations of edible red craw-fish for mirex. The crawfish were taken in May 1971 from six south-central Louisiana parishes that had been treated with mirex. Seven samples showed detectable levels of mirex (0.01 ppm detection level). The results by parish were:

St. Landry, ND - 0.01 ppm
Lafayette, ND
Evangeline, ND - 0.01 ppm

St. Martin, ND - 0.07 ppm
Avoyelles, ND - 0.04 ppm
Vermillion, ND

Wolfe and Norment (1973) monitored the mirex residues in selected organisms in Monroe County, Mississippi, approximately 1 year after mirex bait was aerially applied. Residue levels in fish taken from treated areas were 2 to 20 times higher than those from untreated areas, and the levels of mirex in stream fish remained relatively constant for 7 months after treatment. Ranges in average mirex concentrations in parts per million for the various sampled locations were as follows:

| | November 1971 | April 1972 |
|---|---|---|
| Untreated streams | 0.01 to 0.06 | 0.02 to 0.05 |
| Treated streams | 0.01 to 0.53 | 0.03 to 0.76 |

Samples of wildlife were collected in Mississippi in 1970 and were analyzed for the presence of mirex (Baetcke et al., 1972). The samples were collected 1 year after mirex had been aerially applied in the primary study area. Adipose tissue samples taken from 19 deer from Monroe County showed an average mirex concentration of 0.057 ppm, ranging as high as 0.283 ppm. Concentrations of mirex for other wildlife sampled are as follows:

| Specie | Number Sampled | Liver Samples (ppm) | Adipose Samples (ppm) |
|---|---|---|---|
| Fish (catfish) | 7 | ND - 0.674 | ND - 11.252 |
| Chicken | 1 | 0.550 | 0.087 |
| Bobwhite quail | 20 | ND - 0.295 | ND - 3.148 |
| Brown thrasher | 4 | 0.045 - 1.838 | 19.978 - 59.925 |
| Blue jay | 3 | 0.350 - 1.506 | 5.104 - 104.386 |
| Meadow lark | 3 | 0.350 - 1.506 | -- |
| Turkey | 6 | 0.076 - 0.475 | ND - 1.614 |
| Eastern kingbird | 1 | 0.131 | 0.436 |
| Robin | 5 | ND - 1.443 | 1.002 - 56.536 |
| Barred owl | 1 | 4.072 | -- |

In 1970, 12 groups of 10 starlings each were caputred from areas where mirex had been used. In 10 of the 12 pools, the whole body residues (less skin, beak, feet, and outer wings) ranged from 0.01 to 1.66 ppm (Oberheu, 1972).

Work by others, including Borthwick et al. (1973), Nagvi and De La Cruz (1973), and Collins et al. (1974), demonstrate that low levels of mirex residues remain in the environment and are concentrated in some species' tissues. The work of Collins et al. (1974) is of interest to this study because it investigated and compared mirex residues in selected vertebrates and selected components of the human food chain for 1 year after aerial application of mirex bait in Louisiana. Their data are shown in Table VII-5 and indicate that mirex was detected in 77% of the human food chain items surveyed. Mirex was not detected in beef fat before mirex treatment or for 1 year after treatment. Low levels were found in milk (ND to 0.022 ppm), chicken eggs (ND to 0.493 ppm), and chickens (0.004 to 0.515 ppm).

### 3. Mirex in Hawaian Foods

The mirex monitoring program in Hawaii tests for mirex residues in soils and wildlife in pineapple growing areas--the only place in Hawaii where the pesticide is used; however, no tests have apparently been made about the possibility of mirex contamination of pineapples. The 1972 to 1974 surveys monitored residues in sediments, soils, and aquatic and terrestrial wildlife. Residues in pineapple field soils ranged from 3 to 18 ppb 9 months after mirex had been applied; no residues were found in the sediments. Only 8 fish of 110 aquatic animals sampled contained mirex in levels averaging 3 to 7 ppb. Mirex residues in birds ranged from undetectable to 10 ppb; residues in rodents were quite variable, but in terms of the geometric mean the amount in the Polynesian rat decreased with time from 1270 to 56 ppb. The geometric mean for residues in mongooses decreased from 2200 ppb immediately after application to 238 ppb 39 weeks later. No evidence of mirex residue buildup in the aquatic food chain was apparent, and the higher mirex accumulations in terrestrial biota were temporary (Bevenue et al., 1975; Johnson et al., 1976).

# Table VII-5

## MIREX RESIDUES IN HUMAN FOOD CHAIN FROM PRETREATMENT TO 1 YEAR AFTER SINGLE MIREX APPLICATION*†

| | Mirex Concentration, ppm | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pretreatment | | 2 weeks | | 1 month | | 3 months | | 6 months | | 9 months | | 12 months | |
| Food item | Sample size | Residue found | Sample size | Residue found | Sample size | Residue found | Sample size | Residue found | Sample size | Residue found | Sample size | Residue found | Sample size | Residue found |
| Milk | 1 qt | 0.015 | 1 qt | ND‡ | 1 qt | 0.022 | 1 qt | 0.001 | 1 qt | ND | 1 qt | ND | 1 qt | ND |
| Chicken eggs | 12 | ND | 12 | 0.493 | 12 | 0.005 | 12 | 0.007 | 12 | ND | 12 | 0.011 | 12 | 0.001 |
| Domestic chickens | 2 | -- | 2 | 0.004 | 2 | 0.036 | 2 | 0.515 | 2 | 0.010 | 2 | 0.201 | 2 | 0.014 |
| Beef fat | 1 lb | ND | 0 | -- | 0 | -- | 0 | -- | 0 | -- | 0 | -- | 1 lb | ND |
| Fish | | | | | | | | | | | | | | |
| Bluegills | 28 | 0.003 | 15 | 0.012 | 25 | 0.019 | 79 | 0.041 | 34 | 0.009 | 36 | 0.009 | 13 | 0.018 |
| Brown bullheads | 5 | 0.001 | 6 | 0.004 | 20 | 0.113 | 4 | 0.086 | 7 | 0.003 | 4 | 0.003 | 10 | 0.010 |
| Largemouth bass | 1 | ND | 1 | 0.018 | 1 | 0.032 | 1 | 0.624 | 0 | -- | 0 | -- | 0 | -- |
| Game animals and birds | | | | | | | | | | | | | | |
| Eastern cottontails | 0 | -- | 1 | ND | 1 | ND | 0 | -- | 1 | ND | 1 | 0.254 | 0 | -- |
| Opossums | 1 | 0.120 | 2 | 0.044 | 0 | -- | 1 | 0.099 | 1 | 0.004 | 0 | -- | 0 | -- |
| Bobwhite quail | 1 | 0.113 | 1 | 0.012 | 1 | 0.475 | 1 | 1.502 | 0 | -- | 1 | 0.064 | 2 | 0.036 |

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*Source: Collins et al (1974).

†Average of all samples collected from entire study area at indicated sampling interval.

‡ND - no detectable residues; -- = not sampled.

### 4. Mirex in Spring Creek, Pennsylvania, Fish

The Nease Chemical Company plant, State College, Pennsylvania, is near Spring Creek. The plant has manufactured both mirex and kepone, although reportedly neither is now manufactured. Stockpiles of mirex apparently still exist because Nease continues to supply the material to Hooker Chemical Company.

Spring Creek flows into Bald Eagle Creek, which flows into the West Branch of the Susquehanna, into the Susquehanna River, and thence into upper Chesapeake Bay. Spring Creek is used for sports fishing; apparently no commercial fishing occurs (Pesticide Chemical News, August 11, 1976). The creek has not been closed for sports fishing.

Mirex concentrations of 44 ppb have been found in the creek's sediments near the Nease plant (Clista, 1977) as have kepone concentrations of 35 ppb according to Clista (1977) and 5.33 ppm according to the Pesticide Chemical News (August 11, 1976).

Clista reports that trout and suckers taken with the 18 mi downstream from the plant show kepone concentrations of 0.025 to 0.23 ppm and mirex concentrations of 0.02 to 1.0 ppm. Concentrations of 0.15 to 0.17 ppm kepone in trout and 0.18 ppm kepone in suckers have been reported in the Pesticide Chemical News (August 11, 1976).

### 5. Mirex in Lake Ontario Fish

Lake Description--Lake Ontario has a surface area of 7500 sq mi, a maximum depth of 802 ft, and an average depth of 276 ft. The volume of Lake Ontario is 393 mi$^3$. Its drainage basin land area is 29,500 sq mi. The Niagara River, with a mean flow of 195,000 cfs, contributes 85% of the inflow to the lake (DEC, 1976d).

Much of the shoreline is bounded by bluffs dissected by tributary streams. The eroded shore material, largely silt and clay, probably contributes much of the sediment to the lake (DEC, 1976d).

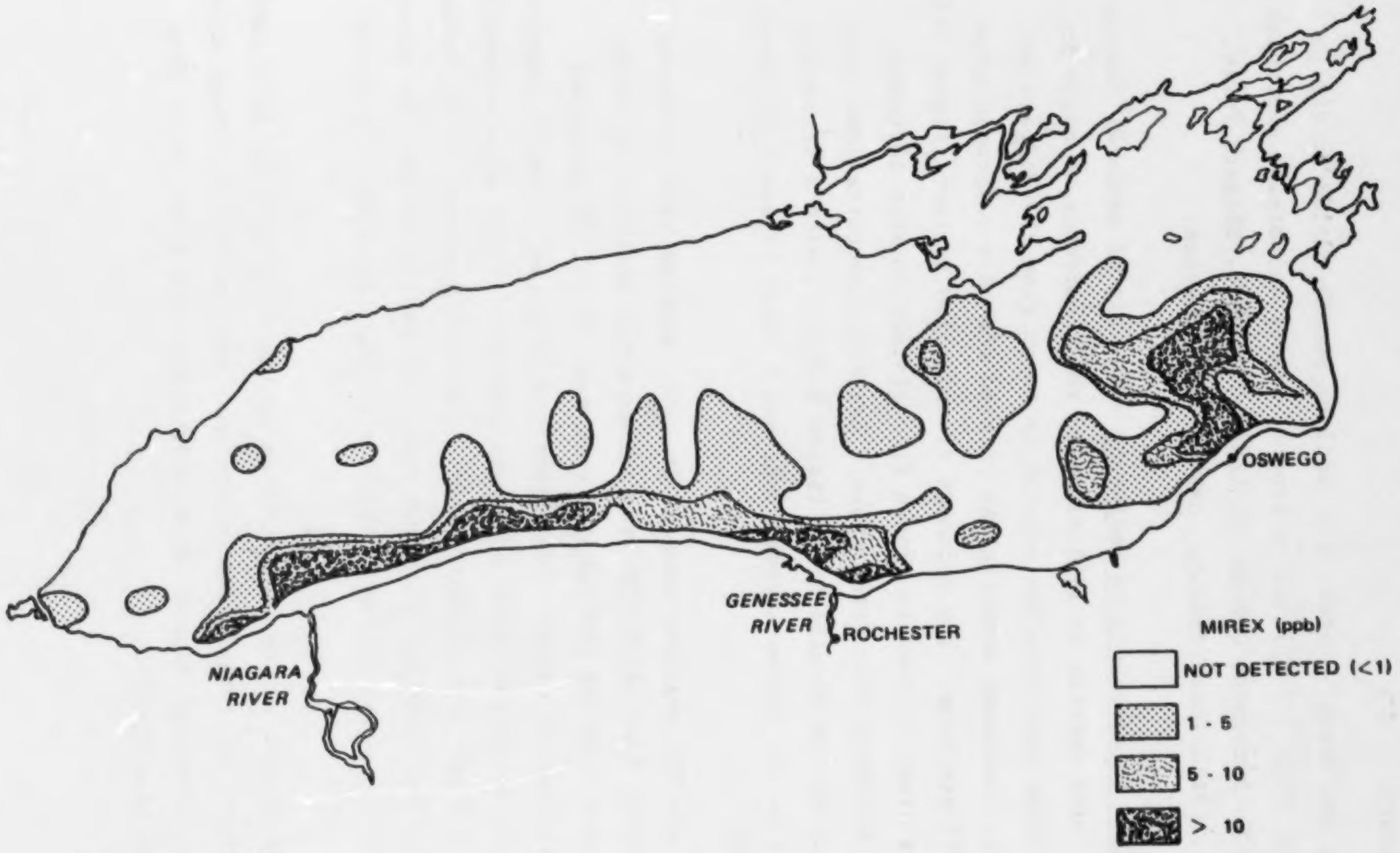
The lake empties into the Atlantic Ocean through the St. Lawrence River. If the inflow of water could displace all the water in the lake, the replacement time on the basis on inflows and the volume of the lake would be 8 years.

In the United States, 2.3 million people reside in the Lake Ontario basin, with 3.8 million in Canada. Major industrial companies are situated in Syracuse, Oswego, Rochester, Buffalo, Niagara Falls, Hamilton, St. Catherines, Toronto, Oshawa, and Kingston.

Mirex in Lake Ontario Sediments--Analysis of sediment samples collected in Lake Ontario in 1968 revealed the occurrence of mirex in two zones of high concentration related to input from the Niagara and Oswego Rivers. Sediment sampling was carried out on a polyconic grid comprising 287 stations. The sediment distribution pattern (Figure VII-1) found in this study follows the known flow of Lake Ontario eastward, close to the southern (New York) shore. Heaviest concentrations occur near the mouth of the Niagara River (below Buffalo), with a secondary concentration in the Rochester embayment and a third adjacent to Oswego (Forest, 1976).

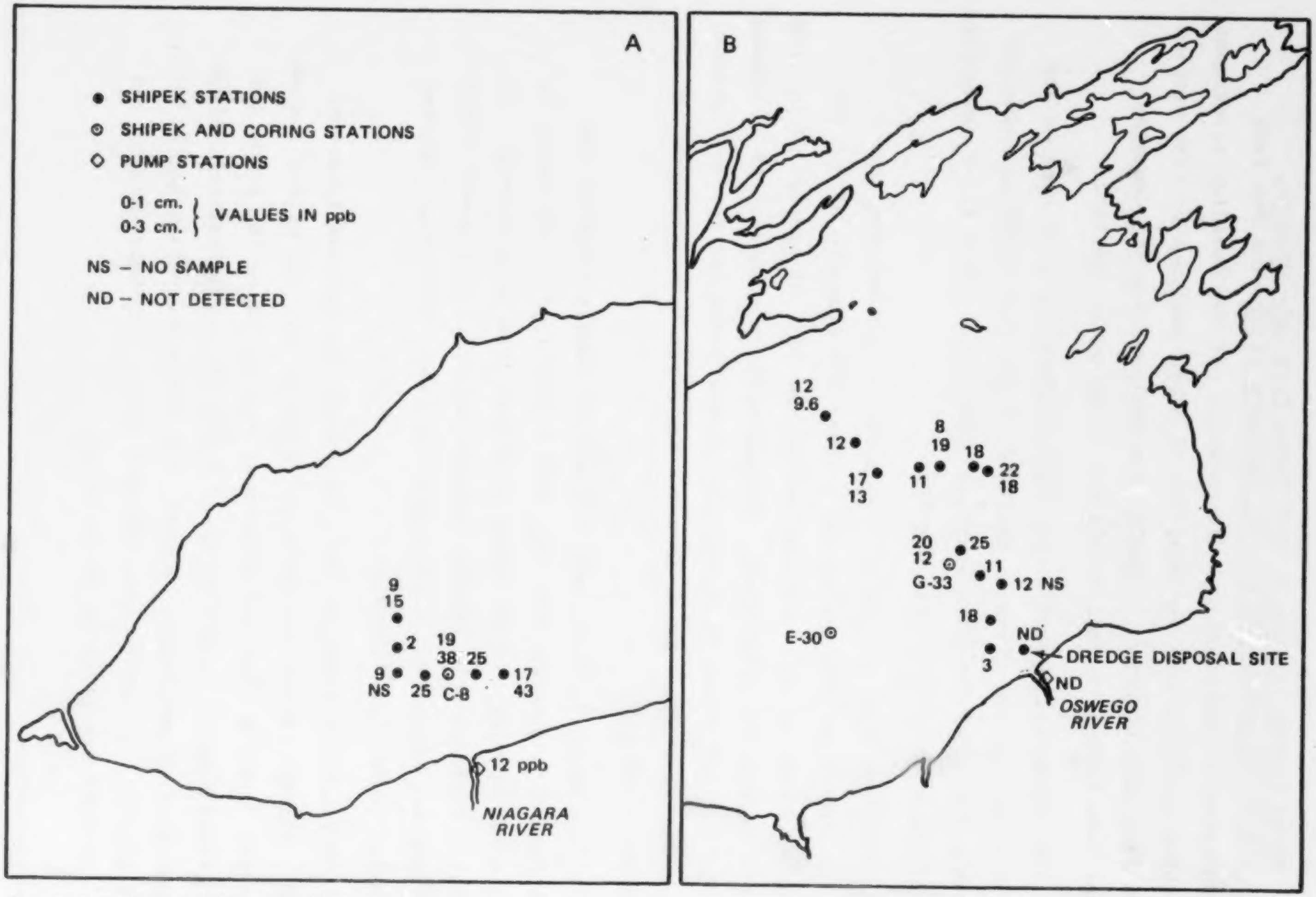
Of the 287 stations sampled in 1968, samples were recovered at 262 locations, from which 229 were subsequently analyzed for mirex residues in 1976. Of the 229 samples analyzed, 75 (32.8% contained detectable residues of mirex. Concentrations of mirex in the 75 samples ranged from 0.7 to 40 ppb, with a mean content of 7.5 ppb and a standard deviation of 8.3 ppb (see Figure VII-2). The 1976 resurvey of the zones of high mirex concentrations recorded from 1968 indicates that the mirex is still in place in the surface sediments of the lake (Van Hove Holdrinent et al., 1977).

A suspended solids sample taken in the Niagara River confirmed an upstream source of mirex. Bottom sediment samples in the Oswego River identified an industrial source 14 km upstream of the river mouth (Van Hove Holdrinet et al., 1977).


OSWEGO
GENESSEE RIVER
ROCHESTER
NIAGARA RIVER
MIREX (ppb)
NOT DETECTED (<1)
1 - 5
5 - 10
> 10

Source: Forest (1976)

FIGURE VII-1. MIREX CONCENTRATIONS IN LAKE ONTARIO SEDIMENTS, 1968


A
• SHIPEK STATIONS
⊙ SHIPEK AND CORING STATIONS
◇ PUMP STATIONS
0-1 cm. } VALUES IN ppb
0-3 cm. }
NS – NO SAMPLE
ND – NOT DETECTED
9
15
2
19
38
25
9
NS
25
C-8
17
43
12 ppb
NIAGARA RIVER
B
12
9.6
12
17
13
8
19
11
18
22
18
20
12
G-33
25
11
12 NS
18
E-30
ND
3
DREDGE DISPOSAL SITE
ND
OSWEGO RIVER

Source: Van Hove Holdrinert, et al (1977)

FIGURE VII-2. MIREX CONCENTRATIONS IN LAKE ONTARIO SEDIMENTS, 1976

Mirex Concentrations in Fish Taken From Lake Ontario, Its Tributaries, and the St. Lawrence River--The New York State Department of Environmental Conservation and the Canadian government have executed or supervised the majority of mirex analyses of fish samples collected from Lake Ontario.* Some of the analyses for the Canadian government have been performed by private firms under contract.

Detailed listings of mirex concentrations by fish species and collection locations are given in Table VII-6 for U.S. sampling locations and in Table VII-7 for Canadian sampling locations. Table VII-8 summarizes mirex occurrence in Lake Ontario species.

From the large sample of fish data, it can be seen that a significant number of fish exceed the present FDA standard of 0.1 ppm. The highest average mirex concentration for the list of species is 0.2 ppm for chinook salmon and lake trout. Average mirex concentrations of approximately 0.1 ppm are shown for brown and rainbow trout and for coho salmon. Smallmouth bass and white perch show average mirex concentrations of approximately 0.08 ppm.

In a March 9, 1977, news release the Hooker Chemical and Plastics Company announced that they were unable to identify mirex in representative samples of fish taken last fall from Lake Ontario. The fish samples included coho salmon, chinook salmon, brown trout, white perch, brown bullheads, white bass, gizzard shad, lake trout, rainbow trout, white suckers, and alewife.

Mirex concentrations for fish taken from various locations on the St. Lawrence River are given in Table VII-9. The higher concentrations are found in fish collected near Massena below the power dam. Species having samples exceeding the 0.1 ppm FDA specification include smallmouth bass, muskellunge, walleye, and white and yellow perch. Overall average mirex concentrations for fish taken from Lake Ontario and the St. Lawrence are given in Table VII-10.

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*See for example OME (1976), Spagnoli (1976), IJC (1976), FDA (1976), DEC (1976a), DEC (1976b), and DEC (1976c).

## Table VII-6

## SUMMARY OF MIREX CONCENTRATIONS OF LAKE ONTARIO FISH BY LOCATION (U.S. Data)

| Species (Location) | Number of Fish Analyzed | Number of Analyses | Mirex (ppm) Average | Mirex (ppm) Range |
|---|---|---|---|---|
| American Eel | | | | |
| Lewiston | 1 | 1 | 0.050 | -- |
| Fort Niagara | 14 | 14 | 0.020 | ND -0.05 |
| Pultneyville | 2 | 2 | 0.250 | 0.17-0.33 |
| Salmon River Estuary | 1 | 1 | ND* | ND |
| Chaumont Bay | 9 | 9 | 0.020 | 0.01-0.07 |
| Total | 27 | 27 | 0.036 | ND -0.33 |
| Largemouth Bass | | | | |
| Braddock and Sodus Bays | 9 | 9 | 0.010 | ND -0.03 |
| Oswego Harbor | 5 | 5 | <0.010 | ND -<0.01 |
| Salmon River Estuary | 9 | 9 | 0.010 | <0.01-0.03 |
| Total | 23 | 23 | 0.009 | ND -0.03 |
| Smallmouth Bass | | | | |
| Pultneyville | 19 | 19 | 0.090 | <0.01-0.31 |
| Nine Mile Point | 10 | 10 | 0.060 | 0.01-0.19 |
| Mexico Bay | 4 | 4 | 0.140 | 0.07-0.29 |
| Salmon River Estuary | 3 | 3 | 0.160 | 0.15-0.18 |
| Chaumont Bay | 11 | 11 | 0.040 | 0.01-0.11 |
| Alan Otty Shoal | 15 | 15 | 0.100 | 0.02-0.30 |
| Total | 62 | 62 | 0.084 | <0.01-0.31 |
| Rock Bass | | | | |
| Chaumont Bay | 6 | 1 | <0.010 | -- |
| Total | 6 | 1 | <0.010 | -- |
| White Bass | | | | |
| Nine Mile Point | 31 | 16 | 0.030 | <0.01-0.11 |
| Oswego Harbor | 6 | 5 | 0.060 | 0.01-0.14 |
| Total | 37 | 21 | 0.039 | 0.01-0.14 |
| Black Crappie | | | | |
| Salmon River Estuary | 2 | 2 | 0.010 | 0.010 |
| Black River Bay | 7 | 1 | <0.010 | -- |
| Total | 9 | 3 | 0.007 | <0.01-0.01 |

---

*ND - None Detected.

Table VII-6 (Continued)

| Species (Location) | Number of Fish Analyzed | Number of Analyses | Mirex (ppm) | |
|---|---|---|---|---|
| | | | Average | Range |
| Brown Bullhead | | | | |
| Fort Niagara | 6 | 2 | 0.030 | 0.02-0.04 |
| Wilson Bay | 7 | 7 | 0.010 | 0.01-0.03 |
| Oswego Harbor | 12 | 3 | 0.010 | ND -0.01 |
| Salmon River Estuary | 11 | 11 | 0.020 | ND -0.04 |
| Chaumont Bay | 34 | 9 | 0.010 | ND -0.01 |
| Total | 70 | 31 | 0.008 | ND -0.04 |
| Northern Pike | | | | |
| Oswego Harbor | 2 | 2 | 0.080 | 0.06-0.10 |
| Salmon River Estuary | 20 | 20 | 0.040 | 0.01-0.09 |
| Chaumont Bay | 18 | 8 | 0.010 | ND -0.07 |
| Total | 40 | 40 | 0.032 | ND -0.10 |
| Pumpkinseed | | | | |
| Chaumont Bay | 9 | 1 | ND | ND |
| Total | 9 | 1 | ND | ND |
| Yellow Perch | | | | |
| Oswego Harbor | 10 | 6 | <0.010 | ND -<0.01 |
| Mexico Bay | 17 | 11 | 0.020 | <0.01-0.030 |
| Wilson Bay | 16 | 2 | <0.010 | ND -<0.01 |
| Chaumont Bay | 15 | 2 | <0.010 | <0.01 |
| Alan Otty Shoal | 12 | 3 | <0.010 | <0.01-0.01 |
| Total | 70 | 24 | 0.007 | ND -0.03 |
| White Perch | | | | |
| Pultneyville | 18 | 9 | 0.090 | <0.01-0.31 |
| Oswego Harbor | 14 | 4 | 0.020 | ND -0.04 |
| Henderson Harbor | 5 | 1 | 0.040 | -- |
| Chaumont Bay | 13 | 4 | 0.030 | 0.01-0.05 |
| Alan Otty Shoal | 20 | 8 | 0.080 | 0.02-0.19 |
| Total | 70 | 26 | 0.072 | ND -0.31 |
| Coho Salmon (lake fish) | | | | |
| Mexico Bay | 2 | 2 | 0.060 | ND -0.12 |
| Salmon River Estuary | 23 | 23 | 0.140 | 0.05-0.50 |
| Total | 25 | 25 | 0.140 | ND -0.50 |

## Table VII-6 (Concluded)

| Species (Location) | Number of Fish Analyzed | Number of Analyses | Mirex (ppm) | |
|---|---|---|---|---|
| | | | Average | Range |
| Coho Salmon (Spring Brook Weir) | | | | |
| Spring Brook Weir | 6 | 6 | 0.020 | 0.01-0.02 |
| Total | 6 | 6 | 0.020 | 0.01-0.02 |
| Chinook Salmon | | | | |
| Mexico Bay | 1 | 1 | 0.130 | -- |
| Salmon River Estuary | 15 | 15 | 0.220 | 0.08-0.36 |
| Total | 16 | 16 | 0.214 | 0.08-0.36 |
| Brown Trout | | | | |
| Wilson | 8 | 8 | 0.080 | 0.01-0.13 |
| Pultneyville | 8 | 8 | 0.120 | < 0.03-0.22 |
| Oswego Harbor | 7 | 7 | 0.100 | 0.07-0.16 |
| Mexico Bay | 8 | 8 | 0.110 | 0.05-0.13 |
| Salmon River Estuary | 9 | 9 | 0.070 | 0.02-0.10 |
| Total | 40 | 40 | 0.096 | 0.01-0.22 |
| Lake Trout | | | | |
| Oak Orchard | 23 | 23 | 0.160 | 0.02-0.42 |
| Mexico Bay | 3 | 3 | 0.250 | 0.04-0.42 |
| Stony Island | 25 | 25 | 0.260 | 0.02-0.97 |
| Total | 51 | 51 | 0.210 | 0.02-0.97 |
| Walley | | | | |
| Oswego Harbor | 4 | 4 | 0.010 | ND -0.02 |
| Total | 4 | 4 | 0.010 | ND -0.02 |
| Rainbow Smelt | | | | |
| Niagara Bar | 75 | 5 | 0.030 | 0.02-0.04 |
| Total | 75 | 5 | 0.030 | 0.02-0.04 |

Table VII-7

## SUMMARY OF MIREX CONCENTRATIONS OF LAKE ONTARIO FISH BY LOCATION (Canadian Data)

| Species (Location) | Number of Fish Analyzed | Number of Analyses | Mirex (ppm) | |
|---|---|---|---|---|
| | | | Average | Range |
| Alewife | | | | |
| Eastern Basin | 5 | 5 | 0.11 | 0.09-0.13 |
| Total | 5 | 5 | 0.11 | 0.09-0.13 |
| Smallmouth Bass | | | | |
| Eastern Basin | 9 | 9 | 0.38 | 0.16-0.64 |
| Total | 9 | 9 | 0.38 | 0.16-0.64 |
| Rock Bass | | | | |
| Eastern Basin | 10 | 10 | 0.09 | ND* -0.24 |
| Total | 10 | 10 | 0.09 | ND -0.24 |
| White Bass | | | | |
| Frenchman's Bay | 7 | 7 | 0.07 | 0.04-0.13 |
| Etobicoke Creek | 5 | 5 | 0.09 | 0.03-0.12 |
| Total | 12 | 12 | 0.08 | 0.03-0.13 |
| Black Crappie | | | | |
| Frenchman's Bay | 3 | 3 | 0.01 | 0.008-0.02 |
| Total | 3 | 3 | 0.01 | 0.008-0.02 |
| Brown Bullhead | | | | |
| Jordan Harbor | 11 | 11 | 0.05 | ND -0.27 |
| Frenchman's Bay | 4 | 4 | 0.14 | 0.08-0.19 |
| Duffins Creek | 10 | 10 | 0.11 | 0.04-0.38 |
| Total | 25 | 25 | 0.09 | ND -0.38 |
| Northern Pike | | | | |
| Frenchman's Bay | 5 | 5 | 0.02 | 0.008-0.04 |
| Etobicoke Creek | 1 | 1 | 0.10 | — |
| St. Georges | 2 | 2 | ND | |
| Total | 8 | 8 | 0.03 | 0.008-0.10 |
| Yellow Perch | | | | |
| Eastern Basin | 10 | 10 | 0.05 | ND -0.17 |
| Frenchman's Bay | 7 | 7 | 0.04 | 0.02-0.09 |
| Duffins Creek | 9 | 9 | 0.25 | 0.08-1.30 |
| Etobicoke Creek | 10 | 10 | 0.05 | 0.02-0.11 |
| St. George's | 1 | 1 | ND | ND |
| Total | 37 | 37 | 0.10 | ND -1.300 |

---

[*] ND - None Detected.

### Table VII-7 (Concluded)

| Species (Location) | Number of Fish Analyzed | Number of Analyses | Mirex (ppm) | |
|---|---|---|---|---|
| | | | Average | Range |
| White Perch | | | | |
| Frenchman's Bay | 2 | 2 | 0.44 | 0.38-0.44 |
| Duffins Creek | 1 | 1 | 0.25 | -- |
| Total | 3 | 3 | 0.38 | 0.25-0.44 |
| Gizzard Shad | | | | |
| Jordan Harbor | 10 | 10 | 0.15 | ND -0.21 |
| Frenchman's Bay | 3 | 3 | ND | ND |
| Total | 13 | 13 | 0.12 | ND -0.21 |
| White Sucker | | | | |
| Frenchman's Bay | 2 | 2 | 0.07 | 0.05-0.08 |
| Duffins Creek | 8 | 8 | 0.04 | 0.03-0.07 |
| Etobicoke Creek | 13 | 13 | 0.03 | 0.002-0.07 |
| Total | 23 | 23 | 0.04 | 0.002-0.08 |
| Bluegill | | | | |
| St. Georges | 10 | 10 | ND | ND |
| Total | 10 | 10 | ND | ND |
| Carp | | | | |
| Frenchman's Bay | 4 | 4 | 0.02 | 0.01-0.05 |
| Total | 4 | 4 | 0.02 | 0.01-0.05 |
| Smelt | | | | |
| Eastern Basin | 5 | 5 | 0.20 | 0.13-0.31 |
| Total | 5 | 5 | 0.20 | 0.13-0.31 |

## Table VII-8

### OVERALL SUMMARY OF MIREX IN LAKE ONTARIO FISH
(U.S. data given in Table VII-6)

| Species | Number of Fish Analyzed | Number of Analyses | Mirex (ppm) | |
|---|---|---|---|---|
| | | | Average | Range |
| American eel | 27 | 27 | 0.036 | ND[*] -0.33 |
| Bass | | | | |
| Largemouth | 23 | 23 | 0.009 | ND -0.03 |
| Smallmouth | 62 | 62 | 0.084 | 0.01-0.31 |
| Rock | 6 | 1 | 0.010 | — |
| White | 37 | 21 | 0.039 | 0.01-0.14 |
| Black crappie | 9 | 3 | 0.007 | 0.01-0.01 |
| Brown bullhead | 70 | 31 | 0.008 | ND -0.04 |
| Northern pike | 40 | 40 | 0.032 | ND -0.10 |
| Perch | | | | |
| Yellow | 70 | 24 | 0.007 | ND -0.03 |
| White | 70 | 26 | 0.072 | ND -0.31 |
| Pumpkinseed | 9 | 1 | ND | ND |
| Rainbow smelt | 75 | 5 | 0.030 | 0.02-0.04 |
| Salmon | | | | |
| Coho-lake | 25 | 25 | 0.140 | ND -0.50 |
| Coho-spring brook weir | 6 | 6 | 0.020 | 0.01-0.02 |
| Chinook | 16 | 16 | 0.214 | 0.08-0.36 |
| Trout | | | | |
| Brown | 40 | 40 | 0.096 | 0.01-0.22 |
| Lake | 51 | 51 | 0.210 | 0.02-0.97 |
| Rainbow | 17 | 17 | 0.103 | ND -0.28 |
| Walleye | 4 | 4 | 0.010 | ND -0.02 |

---

[*] ND = None Detected.

## Table VII-9

## SUMMARY OF MIREX CONCENTRATIONS OF ST. LAWRENCE FISH BY LOCATION

| Species (Location) | Number of Fish Analyzed | Number of Analyses | Mirex (ppm) | |
|---|---|---|---|---|
| | | | Average | Range |
| American Eel | | | | |
| Massena--below dam | 14 | 14 | 0.030 | ND -0.09 |
| Total | 14 | 14 | 0.030 | ND -0.09 |
| Brown Bullheads | | | | |
| Alexandria Bay | 15 | 7 | 0.005 | <0.01-0.01 |
| Total | 15 | 7 | 0.005 | <0.01-0.01 |
| Smallmouth Bass | | | | |
| Cape Vincent | 12 | 12 | 0.080 | 0.01-0.36 |
| Alexandria Bay | 6 | 6 | 0.060 | 0.01-0.09 |
| Ogdensburg | 11 | 11 | 0.060 | <0.01-0.23 |
| Massena--below dam | 17 | 17 | 0.060 | <0.01-0.27 |
| Total | 46 | 46 | 0.062 | <0.01-0.36 |
| Lake Sturgeon | | | | |
| Massena--below dam | 1 | 1 | ND* | ND |
| Total | 1 | 1 | ND | ND |
| Muskellunge | | | | |
| Cape Vincent | 1 | 1 | 0.080 | -- |
| Carleton Is. | 2 | 2 | 0.080 | 0.04-0.11 |
| Ogdensburg | 1 | 1 | 0.040 | -- |
| Total | 4 | 4 | 0.070 | 0.04-0.11 |
| Northern Pike | | | | |
| Ogdensburg | 3 | 3 | 0.050 | 0.04-0.07 |
| Massena--below dam | 1 | 1 | 0.090 | -- |
| Total | 4 | 4 | 0.060 | 0.04-0.09 |
| Walleye | | | | |
| Massena--below dam | 7 | 7 | 0.020 | 0.01-0.10 |
| Total | 7 | 7 | 0.020 | 0.01-0.10 |

---

*ND = None Detected.

Table VII-9 (Concluded)

| Species (Location) | Number of Fish Analysed | Number of Analyses | Mirex (ppm) Average | Mirex (ppm) Range |
|---|---|---|---|---|
| White Bass | | | | |
| Massena--below dam | 4 | 4 | 0.020 | ND -0.07 |
| Total | 4 | 4 | 0.020 | ND -0.07 |
| White Perch | | | | |
| Massena--below dam | 14 | 14 | 0.097 | ND -0.19 |
| Total | 14 | 14 | 0.097 | ND -0.19 |
| Yellow Perch | | | | |
| Ogdensburg | 9 | 4 | <0.01 | ND -0.03 |
| Massena--below dam | 10 | 8 | 0.05 | 0.01-0.11 |
| Total | 19 | 12 | 0.03 | ND -0.11 |

## Table VII-10

## SUMMARY OF MIREX CONCENTRATIONS IN FISH TAKEN FROM LAKE ONTARIO, ITS TRIBUTARIES, AND THE ST. LAWRENCE RIVER[*]

| Species | Assumed Average Mirex Concentration (ppm) |
|---|---|
| Lake Ontario and Its Tributaries | |
| Alewife | 0.11 |
| American eel | 0.05 |
| Brown trout | 0.11 |
| Brown bullheads | 0.03 |
| Black crappy | <0.01 |
| Bluegill | ND[†] |
| Chinook salmon | 0.21 |
| Coho salmon | 0.20 |
| Catfish | 0.27 |
| Chain pickerel | ND |
| Carp | 0.02 |
| Gizzard shad | 0.11 |
| Herring | ND |
| Lake trout | 0.21 |
| Largemouth bass | 0.01 |
| Northern pike | 0.03 |
| Pumpkinseed | ND |
| Rainbow trout | 0.06 |
| Rainbow smelt | 0.13 |
| Rock bass | 0.03 |
| Shiners | ND |
| Smallmouth bass | 0.11 |
| Smelt | 0.02 |
| Suckers | 0.02 |
| Walleyed pike | 0.06 |
| White bass | 0.05 |
| White perch | 0.09 |
| Yellow perch | 0.05 |
| St. Lawrence River | |
| Muskellunge | 0.07 |
| Northern pike | 0.06 |
| Smallmouth bass | 0.06 |
| Walleyed pike | 0.02 |
| White perch | 0.10 |
| Yellow perch | 0.03 |
| American eel | 0.03 |
| White bass | 0.02 |
| Brown bullheads | 0.01 |

---

[*] Average of U.S. and Canadian sources as of February 18, 1977.

[†] ND - None Detected.

Regulations for the Consumption of Lake Ontario Fish--On September 14, 1976, the New York State Health Department and Department of Environmental Conservation prohibited the possession (and consequently, the opportunity to eat) of several species of fish from the Lake Ontario watershed; coho and chinook salmon, brown bullheads, catfish, lake trout, smallmouth bass, and the alewife-herring group. In addition, pregnant women were warned not to eat smelt, white perch, and white bass, and all others were cautioned to eat these fish no more than once a week (DEC, 1976d).

On October 2, 1976, the order prohibiting possession was modified so that anglers fishing for coho and chinook salmon and smallmouth bass in Lake Ontario and its tributaries are permitted to keep up to three trophy-size fish, provided these fish are identified in accordance with regulations (DEC, 1976d).

On March, 1977, the ban was lifted; all bullheads, chinook, lake trout, and brown trout under 18 in. can be kept, and steelhead and rainbows under 25 in. can be kept. Smallmouth bass, American eel, catfish other than bullheads, and alewife-herrings are still banned. Eating bullheads is recommended no more than once a week, and none should be eaten by pregnant women, nursing mothers, or children. Trophy fish can be kept for coho, chinook salmon, and for smallmouth bass (F. David, Syracuse Herald-American, March 20, 1977).

Canada's Ontario Resources Ministry has banned commercial fishing for coho and chinook salmon in Lake Ontario and other bodies of water because of concentrations of mirex found in them. No ban has been imposed on sports fishing catches; however, Ontario recommends that all varieties of fish taken from these waters be eaten no more than once a week. The commercial ban extends farther than the shores of Lake Ontario; taking coho and chinook salmon is banned for Lake Ontario, as are eels from the St. Lawrence River. The ban is expected to be extended to include catfish in the St. Lawrence and eels in Lake Ontario (Sports Fishing Institute, 1976).

Mirex Concentrations for Fish Taken from Lake Erie--No known discharges of mirex have occurred in Lake Erie; however, the Ontario Ministry of Agriculture and Food obtained and ananlyzed samples of fish taken from the alke to determine if contamination might exist (IJC, 1976). Species samples were minnow, rainbow smelt, coho salmon, and chinook salmon. Of the more than 300 samples analyzed (Table VII-11), none was found to contain detectable levels of mirex.

Table VII-11

SUMMARY OF MIREX CONCENTRATIONS OF LAKE ERIE FISH

| Species | Number of Fish Analyzed | Number of Analyses | Average | Range |
|---|---|---|---|---|
| Minnow, assorted | 150 | 30 | ND* | ND |
| Rainbow smelt | 150 | 20 | ND | ND |
| Coho salmon | 2 | 2 | ND | ND |
| Chinook salmon | 4 | 4 | ND | ND |

---

*ND - None Detected.
Source: IJC (1976).

## B. Kepone in Foods

### 1. General

The established tolerances for kepone in foods generally pertain to aquatic organisms and are as follows: 0.3 ppm for shellfish, 0.1 ppm for finfish, and 0.4 ppm for crabs. In addition, because kepone is used to control the banana root borer (the only current food or feed use of kepone), a limit of 0.01 ppm has been established for banana peels. This limit is presumed to result in kepone concentrations of less than 0.005 ppm in banana meat. On April 10, 1977, the action level for kepone in finfish was increased to 0.3 ppm.

The major geographic areas expected to produce kepone contaminated foods are aquatic systems that have received kepone emissions from product manufacturers. These would include Spring Creek, Pennsylvania; the James River and Cheaspeake Bay; and the eastern coast of the Atlantic Ocean. Lesser concentrations might be expected in food taken from the southeastern United States.

Uptake and accumulation of kepone in food products is expected to follow mechanisms similar to mirex. The accumulation, transfer, and loss of kepone in estuarine food chains was studied in laboratory bioassays by Bahner et al. (1976). Kepone was bioconcentrated by oysters, mysids, grass shrimp, sheepshead minnows, and spot, from concentrations as low as 0.023 μg/L seawater. Depuration of kepone from oysters was rapid; however, clearance of kepone from crustacea and fish was relatively slow, with tissue concentrations requiring 24 to 28 days to decrease 30 to 50%.

Kepone was fed to dairy cows in concentrations of 0.25 to 5.0 ppm for 60 days. The highest residue level in milk recorded from an individual cow was 0.44 ppm. No measurable amounts of kepone were present in milk 83 days after discontinuing treatment (Smith and Arent, 1976).

The FDA marketbasket survey, which records contaminants in foods, does not examine for kepone residues.

### 2. Kepone in Food from Southeastern United States

Kepone could be present in the southeastern United States in areas that were treated with mirex for fire ant control because mirex can degrade into kepone (Carlson et al., 1976), because kepone has been found to be a co-contaminant of mirex (Pesticide Chemical News, August 4, 1976), and because some kepone was used for pest control on southeastern U.S. agriculture. To test for its presence in fishery products, the FDA (FDA, 1977) conducted 11 surveys and gathered 132 samples. These included samples of finfish, shellfish, and crustacea taken from eight southeastern states. Although mirex was found in numerous finfish sample in this survey, no kepone was detected. In fact, only one crab sample from Georgia contained kepone (trace level), and no mirex was detected.

Bender (1977) reports that data collected by the Virginia Department of Agriculture have shown that no source of kepone exists in nonaquatic food products. These data are shown in Table VII-13. The only samples showing kepone concentrations were ice taken from Hopewell at a location near the Life Sciences plant (as high as 50 ppb), crabmeal (as high as 0.27 ppm), and fishmeal (as high as 0.06 ppm).

### 3. Kepone in Atlantic Ocean Fish

Since the summer of 1976, the North Carolina Department of Agriculture has studied kepone levels in fish and shellfish along the North Carolina coast. According to the FDA (1977), crabs, oysters, and shrimp showed negligible levels of kepone. All samples of spot, flounder, mullet, trout, and croakers were below the 0.1 ppm action level. Bluefish were generally higher than other finfish, but only one sample (0.2 ppm) exceeded the action level. The North Carolina Department of Agriculture noted an increase in kepone in the October-November samples for certain species and attributed the increase to fall migration.

FDA Field Districts were to collect one bluefish sample per week (for 10 weeks) landed at coastal ports in the Mid and South Atlantic states to be tested for kepone concentrations (FDA, 1977). This program resulted in the collection and analysis of 66 bluefish samples collected along the Atlantic coast from Boston, Massachusetts, to Ft. Lauderdale, Florida. The results are tabulated in Table VII-12 by collection point. Average kepone concentrations by collection locations ranged from none detectable to 0.04 ppm. The average of all samples was 0.014 ppm and the range was none detected to 0.06 ppm. The highest concentrations were found in the Virginia samples (average of 0.04 ppm) as expected because the Chesapeake Bay is presumed to be the major source of residual kepone on the Atlantic Coast.

### 4. Kepone in Bananas

The only large-scale U.S. use of kepone on food and feed has been for control of the banana root borer in Puerto Rico. The kepone-

## Table VII-12

## SUMMARY OF FY77 KEPONE AND MIREX COMPLIANCE EVALUATION PROGRAM FOR ATLANTIC COAST BLUEFISH

| Collection Point | Sample Size | Kepone (ppm) | | |
|---|---|---|---|---|
| | | Average | Minimum | Maximum |
| Boston, MA | 8 | 0.01 | ND* | 0.02 |
| Calilee, RI | 1 | trace | -- | -- |
| Point Judith, RI | 1 | trace | -- | -- |
| Sheepshead Bay, NY | 2 | 0.02 | 0.02 | 0.02 |
| Brooklyn, NY | 1 | trace | -- | -- |
| Freeport, NY | 9 | trace | -- | -- |
| Sandy Hook Bay, NY | 2 | 0.02 | 0.02 | 0.03 |
| Cape May, NJ | 3 | trace | -- | -- |
| Absecon, NJ | 1 | 0.02 | -- | -- |
| Atlantic City, NJ | 6 | 0.01 | trace | 0.03 |
| Lewes, DE | 2 | 0.02 | 0.02 | 0.02 |
| Hampton, VA | 9 | 0.04 | 0.01 | 0.06 |
| Morehead City, NC | 10 | trace | ND | 0.02 |
| Nags, NC | 1 | trace | -- | -- |
| Miami, FL | 8 | ND | -- | -- |
| Deerfield Beach, FL | 1 | ND | -- | -- |
| Ft. Lauderdale, FL | 1 | ND | -- | -- |
| Total | 66 | 0.014 | ND | 0.06 |

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*ND - None Detected.

Source: FDA (1977).

## Table VII-13

## KEPONE CONCENTRATIONS OF VIRGINIA AGRICULTURAL PRODUCTS

| Collection Date | Product | Collection Location | Sample Origin | Test Results |
|---|---|---|---|---|
| 12/17/75 | Ensilage/corn | Hopewell | Farm silo | ND* |
| 1/30/76 | Crude peanut oil | Suffolk | Oil mill | ND |
| 3/8/76 | Bee honey | Hopewell | Producer | ND |
| 3/8/76 | Bee honey | Hopewell | Producer | ND |
| 3/8/76 | Bee honey | Hopewell | Producer | ND |
| 3/8/76 | Bee honey | Hopewell | Producer | ND |
| 3/8/76 | Home canned-cucumber pickles | Hopewell | Producer | ND |
| 3/8/76 | Home canned-green beans | Hopewell | Producer | ND |
| 12/10/75 | Ice, 10-lb bag | Hopewell | Ice processor | 11.1 ppb |
| 12/10/75 | Ice, floor | Hopewell | Ice processor | 1.2 ppb |
| 12/10/75 | Ice, block | Hopewell | Ice processor | 50.0 ppb |
| 12/10/75 | Tap water | Hopewell | Ice processor | ND |
| 1/2/76 | Pole beans (fresh) | Hopewell | Producer | ND |
| 1/2/76 | Kale (fresh) | Hopewell | Retail store | ND |
| 1/2/76 | Beef chuck roast | Hopewell | Retail store | ND |
| 12/15/75 | Oats | Prince George | Producer | ND |
| 12/16/75 | Peanuts | Prince George | Producer | ND |
| 12/15/75 | Soybeans | Prince George | Producer | ND |
| 12/15/75 | Corn | Prince George | Producer | ND |
| 12/15/75 | Corn | Prince George | Producer | ND |
| 12/16/75 | Corn | Prince George | Producer | ND |
| 12/16/75 | Soybeans | Prince George | Producer | ND |
| 12/16/75 | Soybeans | Charles City | Producer | ND |
| 12/17/75 | Corn | Hopewell | Producer | ND |
| 12/17/75 | Wheat | Prince George | Producer | ND |
| 12/17/75 | Raw peanuts | Prince George | Producer | ND |
| 12/17/75 | Soybeans | Prince George | Producer | ND |
| 12/17/75 | Corn | Prince George | Producer | ND |
| 12/19/75 | Soybeans | Charles City | Producer | ND |
| 12/19/75 | Corn | Charles City | Producer | ND |
| 12/19/75 | Soybeans | Chester | Producer | ND |
| 12/18/75 | Soybeans | Charles City | Producer | ND |
| 12/18/75 | Corn | Charles City | Producer | ND |
| 12/18/75 | Corn | Charles City | Producer | ND |
| 12/18/75 | Soybeans | Charles City | Producer | ND |
| 12/18/75 | Soybeans | Charles City | Producer | ND |
| 12/18/75 | Corn | Charles City | Producer | ND |

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*ND = None Detected.

## Table VII-13 (Continued)

| Collection Date | Product | Collection Location | Sample Origin | Test Results |
|---|---|---|---|---|
| 12/15/75 | Soybeans | Prince George | Producer | ND |
| 12/15/75 | Wheat | Prince George | Producer | ND |
| 8/10/76 | Ice | Hopewell | Ice processor | 0.1 ppb |
| 8/11/76 | Ice | Hopewell | Ice processor | 0.03 ppb |
| 8/17/77 | Chicken | Sandston | Richmond, VA - processor | ND |
| 8/17/76 | Ham | Sandston | Surry, VA - processor | ND |
| 8/20/76 | Chicken | Richmond | Wilkesboro, NC - processor | ND |
| 8/20/76 | Pork sausage | Richmond | Courtland, VA - processor | ND |
| 8/23/76 | Chicken | Richmond | Fort Wayne, IN processor | ND |
| 8/24/76 | Peppers (fresh) | Hopewell | Retail store | ND |
| 8/24/76 | Stringbeans (fresh) | Hopewell | Retail store | ND |
| 8/24/75 | Squash (fresh) | Hopewell | Retail store | ND |
| 8/24/76 | Tomatoes (fresh) | Hopewell | Retail store | ND |
| 8/24/76 | Lettuce (fresh) | Hopewell | Retail store | ND |
| 8/24/76 | Potatoes (fresh) | Hopewell | Retail produce | ND |
| 8/24/76 | Grapes (fresh) | Hopewell | Retail produce | ND |
| 8/24/76 | Collards (fresh) | Hopewell | Retail store | ND |
| 8/26/76 | Lettuce (fresh) | Hopewell | Retail store | ND |
| 9/7/76 | Ice | Richmond | Ice plant | ND |
| 10/27/76 | Ice (block) | Richmond | Ice plant | ND |
| 10/27/76 | Ice (bags) | Richmond | Ice plant | ND |
| 10/27/77 | Ice (block) | Hopewell | Ice processor | 0.20 ppb |
| 10/27/77 | Ice (bags) | Hopewell | Ice processor | ND |
| 10/23/76 | Tuna salad sandwich | Richmond | Norfolk, VA - processor | ND |
| 5/18/76 | Crab meal | Morattico | Processing plant | 0.03 ppm |
| 5/11/76 | Crab meal | Hayes | Processing plant | 0.15 ppm |
| 5/19/76 | Crab meal | Lottsburg | Processing plant | 0.27 ppm |
| 11/18/76 | Crab meal | Hayes | Processing plant | 0.02 ppm |
| 11/18/76 | Crab meal | Morattico | Processing plant | 0.04 ppm |
| 11/2/76 | Crab meal | Lottsburg | Processing plant | ND |
| 9/14/76 | Crab meal | Morattico | Processing plant | ND |
| 9/22/76 | Crab meal | Hampton | Processing plant | 0.03 ppm |

Table VII-13 (Concluded)

| Collection Date | Product | Collection Location | Sample Origin | Test Results |
|---|---|---|---|---|
| 9/22/76 | Crab meal | Hampton | Processing plant | 0.08 ppm |
| 9/22/76 | Crab meal | Hayes | Processing plant | ND |
| 10/5/76 | Crab meal | Lottsburg | Processing plant | ND |
| 5/19/76 | Fish meal | Reedville | Processing plant | ND |
| 11/12/76 | Fish meal | Cape Charles | Processing plant | 0.02 ppm |
| 11/12/76 | Fish meal | Cape Charles | Processing plant | 0.02 ppm |
| 10/13/76 | Fish meal | Cape Charles | Processing plant | 0.02 ppm |
| 10/27/76 | Fish meal | Fairport | Processing plant | 0.06 ppm |
| 12/13/76 | Fish meal | Cape Charles | Processing plant | ND |
| 12/13/76 | Fish meal | Cape Charles | Processing plant | ND |
| 12/13/76 | Fish meal | Cape Charles | Processing plant | ND |
| 11/12/76 | Fish meal | Cape Charles | Processing plant | ND |
| 11/16/76 | Fish meal | Horsey | Processing plant Portmonmouth, NJ | ND |
| 11/16/76 | Fish meal | Reedville | Processing plant | ND |
| 11/16/76 | Fish meal | Fairport | Processing plant | ND |
| 10/27/76 | Fish meal | Reedville | Processing plant | ND |
| 9/13/76 | Fish meal | Broadway | Processing plant Reedville, VA | ND |
| 9/14/76 | Fish meal | Fairport | Processing plant | ND |
| 9/14/76 | Fish meal | Reedville | Processing plant | ND |
| 9/14/76 | Fish meal | Cape Charles | Processing plant | ND |
| 9/14/76 | Fish meal | Cape Charles | Processing plant | ND |
| 9/14/76 | Fish meal | Cape Charles | Processing plant | ND |
| 10/8/76 | Fish meal | Fairport | Processing plant | ND |
| 10/8/76 | Fish meal | Reedville | Processing plant | ND |
| 10/13/76 | Fish meal | Cape Charles | Processing plant | ND |
| 10/13/76 | Fish meal | Cape Charles | Processing plant | ND |
| 10/14/76 | Fish meal | Horsey | Processing plant Portmonmouth, NJ | ND |
| 10/8/76 | Fish solubles | Fairport | Processing plant | ND |
| 9/14/76 | Fish solubles | Fairport | Processing plant | ND |
| 10/27/76 | Fish solubles | Fairport | Processing plant | ND |
| 11/16/76 | Fish solubles | Fairport | Processing plant | ND |

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NOTE: Ice samples from Hopewell, Virginia, were collected from an ice processor within approximately 50 yards of Life Sciences Products Company. The processor crushes and bags ice, which is manufactured by a Richmond, Virginia, ice plant. The ice processor was closed and moved to another location for approximately 8 months.

Source: Virginia Department of Agriculture and Commerce.

treated bananas could represent a source of possible human exposure. Tolerance limits of 0.01 ppm have been established for banana peels, with 0.005 ppm for banana meat. Concentrations of kepone lower than the tolerances are presumed to be present in the meat but at less than the 0.005 ppm level of detectability (U.S. EPA 1975a). Other food products could be contaminated from runoff of the kepone applied to the base of the banana stem. EPA reportedly has no data on the extent of this runoff nor on residue levels in streams or in aquatic organisms. The extent of wildlife feeding at the base of banana plants is unknown (U.S. EPA, 1976a).

### 5. Chesapeake Bay and the James River

Description--Chesapeake Bay is a coastal-plain estuarine system formed from the submerged valleys of the Susquehanna River and its tributaries, including the Potomac, the James, the York, and the Rappahannock. In addition, dozens of smaller tributaries drain into arms inlets, and bays on all sides, giving the Bay the appearance of a complicated branching system. The southernmost arm of the system, the James River, was probably a separate river flowing into the ocean through its own estuary before the area was flooded by the present sea level (Gross, 1972).

The total volume of fresh water discharged each year by rivers flowing into Chesapeake Bay approximately equals the total volume of the estuary. The Susquehanna River supplies 49% of the annual fresh-water discharge, the Potomac River contributes 18%, and the James River about 15%.

The James River estuary area is considered to be 650 $km^2$ of a total Bay area of 10,000 $km^2$. The James River has an annual freshwater discharge of 10 $km^3$/yr and drains about 26,000 $km^2$. The distance from Hopewell, Virginia, where major kepone discharges have occurred, to the Chesapeake Bay is approximately 100 km.

Kepone in James River Sediments--The EPA estimates that 100,000 lb of kepone is in the James River. Baileys Bay on the James River is estimated to be the repository for approximately 15-25% of the kepone in the river's sediments. It is further estimated that 10% of the sediments in the James River could be expected to move into the Chesapeake Bay (Pesticide Chemical News, November 3, 1976).

Kepone levels in sediments taken from Baileys Bay on the James River ranged between 1.0 and 9.99 ppm in about three-fourths of the samples. In Baileys Creek, kepone levels in sediments were as high as 30 ppm (Pesticide Chemical News, November 3, 1976).

Kepone Concentrations for Fish Taken From the Chesapeake Bay and the James River--The concentrations of kepone in fish reported here are primarily based on data collected during 1976. The Fisheries Monitoring Program (Bender, 1977) was designed to collect kepone residue information on major marine and freshwater organisms as a function of location and season of the year. Since January 1, 1976, approximately 5,000 samples of finfish, oysters, and crabs taken from the James River and the Chesapeake Bay have been analyzed for kepone by Virginia and Maryland state laboratories. This number does not include hundreds of analyses of water and sediments from various locations, nor does this number include the many analyses made by federal laboratories.

Results of the oyster part of the monitoring program in the James (Table VII-14) have shown that the kepone in oysters generally remains below the present action level of 0.3 ppm. Residue levels were found to increase in early summer while the oysters are fattening in preparation for spawning, decline after spawning, and then increase again. On the basis of these data, the James was reopened for the taking of adult oysters on May 21, 1976, and has remained open. The major value of the oyster beds in the James is their production of seed oysters (i.e., small oysters) for transplanting in other areas in the Bay. Experiments have shown that oysters depurate their kepone residues rapidly; therefore, the James was also reopened for the taking of seed oysters (Bender, 1977). The average concentration of kepone in James River oysters was 0.14 to 0.22 ppm.

## Table VII-14

## KEPONE IN JAMES RIVER OYSTER ROCKS

| Sample Location | Sample Size[*] | Kepone (ppm) | | |
|---|---|---|---|---|
| | | Average | Minimum | Maximum |
| Mouth of Nansemond River | 12 | 0.14 | 0.05 | 0.21 |
| Nansemond Ridge | 14 | 0.15 | ND[†] | 0.33 |
| Naseway Shoals | 14 | 0.16 | ND | 0.26 |
| Ballards Marsh | 9 | 0.19 | 0.05 | 0.41 |
| Mouth of Pagan River | 12 | 0.16 | 0.04 | 0.28 |
| White Shoal | 8 | 0.19 | 0.11 | 0.36 |
| Miles Watch House | 14 | 0.14 | ND | 0.27 |
| Point of Shoals | 14 | 0.22 | 0.03 | 0.40 |
| Wreck Shoals | 9 | 0.19 | 0.13 | 0.31 |
| Jail Point | 13 | 0.20 | 0.04 | 0.45 |
| Swash Hole | 13 | 0.19 | 0.08 | 0.32 |
| Deep Water Shoals | 13 | 0.21 | ND | 0.44 |
| Horse Head | 9 | 0.18 | 0.05 | 0.31 |
| Blunt Point | 4 | 0.18 | 0.09 | 0.41 |
| Total | 158 | 0.17 | ND | 0.45 |

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[*] Number of calendar months with representative data.

[†] ND - None Detected.

Source: Bender (1977)

Blue crabs from the James River have also been monitored for kepone. Male crabs spend more time upriver in fresher water than do females. Forty-three samples of males have been collected from the James, with an average kepone residue of 0.81 ppm; therefore, the entire James River is closed to commercial harvesting of male crabs. Around the mouth of the river (i.e., from Newport News Point to Seawells Point), female crabs average 0.19 ppm, below the present action level; hence, this area is open to crabbing. Upriver from this line females average 0.28 ppm, but the area remains closed because of the high ratio of males to females in this area. Blue crab samples collected from the Bay average 0.07 ppm, well below the action level (Bender, 1977).

The residue levels determined for James River fish as part of the Fisheries Monitoring Program are shown in Table VII-15. Freshwater fish in the James, with the exception of the channel catfish and anadromous marine fishes such as the shad and herring, generally exceed the present action level of 0.1 ppm by factors as high as 20. The largemouth bass and black crappie show average concentrations in excess of 1 ppm. In the lower James, where marine fishes are the primary concern, there are three types of populations: (1) fishes like shad, which traverse the river to spawn in the upper freshwater portions and leave after spawning; (2) fishes like croakers, which move into the estuary and use it as a feeding ground during the summer and then return to the ocean; and (3) resident estuarine fish, like white perch, which spend their entire lives in the estuary (Bender, 1977).

During the early spring, samples showed that shad moving into the lower James had kepone residues below the present action level, but the longer they remained, the more kepone they accumulated. After several weeks, approximately 30% of the shad samples at the upstream stations exceeded the present action level (Bender, 1977).

Summer resident marine fishes (bluefish, spot, croaker, striped mullet, and grey trout) showed average kepone concentrations of 0.4 to 1.2 ppm. The concentrations for striped bass and speckled trout were much lower (0.04 and 0.07 ppm).

Table VII-15

## KEPONE IN JAMES RIVER FISH

| Specie | Sampling Location | Sample Size | Average Kepone (ppm) |
|---|---|---|---|
| Channel catfish | Unspecified | 205 | 0.04 |
| White catfish | Unspecified | 32 | 0.16 |
| Largemouth bass | Unspecified | 36 | 1.12 |
| Black crappie | Unspecified | 23 | 1.03 |
| Shad | Zone Q | 26 | 0.02 |
| | Zone A | 34 | 0.02 |
| | Zone B | 35 | 0.02 |
| | Zone C | 23 | 0.07 |
| | Weyonoke | 10 | 0.12 |
| | All Zones | 128 | 0.04 |
| Bluefish | Unspecified | 23 | 0.65 |
| Spot | Unspecified | 16 | 0.75 |
| Croaker | Unspecified | 33 | 0.62 |
| Striped mullet | Unspecified | 4 | 0.37 |
| Striped bass | Unspecified | 8 | 0.04 |
| Grey trout | Unspecified | 4 | 1.21 |
| Speckled trout | Unspecified | 8 | 0.07 |
| American eel | Unspecified | 16 | 2.37 |
| Oyster toad | Unspecified | 3 | 2.53 |
| Hogchoker | Unspecified | 18 | 0.93 |
| White perch | Unspecified | 31 | 2.06 |

Source: Bender (1977).

Kepone residues in estuarine resident fish like the American eel, oyster toad, hogchoker, and white perch showed average kepone concentrations of 0.9 to 2.5 ppm.

Most of the Fisheries Monitoring Program in Chesapeake Bay has been devoted to testing kepone in finfish. However, oysters were collected from 12 bay locations, with no kepone detected in any of the samples. Similarly, hard clams from the bay have shown only trace amounts of kepone (Bender, 1977).

Table VII-16 gives average kepone levels found in finfish taken from the Chesapeake Bay as part of the monitoring program. The average concentrations varied from 0.03 to 0.08 ppm.

The FDA conducted an FY77 Compliance Evaluation Program to determine if commercially marketed finfish, crustacea, and shellfish from Virginia and Maryland comply with guideline kepone concentrations (FDA, 1977); 102 samples were collected, composed of 12 species, from eastern U.S. commercial marketplaces. The data collected, 94 (92%) contained detectable levels of kepone, the median of all samples was 0.03 ppm.

Table VII-16

KEPONE IN CHESAPEAKE BAY FISH

| Specie | Sample Size | Average Kepone (ppm) |
|---|---|---|
| Bluefish | 412 | 0.03 |
| Croakers | 249 | 0.06 |
| Grey trout | 106 | 0.05 |
| Flounder | 45 | 0.08 |
| Spot | 86 | 0.03 |
| Total | 898 | 0.04 |

Source: Bender (1977).

## Table VII-17

### SUMMARY OF FY77 KEPONE AND MIREX COMPLIANCE EVALUATION PROGRAM FOR MARYLAND AND VIRGINIA FISHERY PRODUCTS

| Species/ Place of Collection | Sample | Kepone (ppm) Average | Kepone (ppm) Minimum | Kepone (ppm) Maximum |
|---|---|---|---|---|
| **Croaker** | | | | |
| Cape Charles, VA | 1 | 0.04 | -- | -- |
| Baltimore, MD | 7 | 0.03 | 0.01 | 0.06 |
| Hampton Roads, VA | 2 | 0.01 | trace | 0.02 |
| New York, NY | 4 | 0.06 | 0.02 | 0.09 |
| Washington, DC | 2 | 0.02 | 0.02 | 0.02 |
| Whitestone, VA | 1 | 0.02 | -- | -- |
| Philadelphia, PA | 4 | 0.04 | 0.02 | 0.06 |
| Total | 21 | 0.03 | trace | 0.09 |
| **Bluefish** | | | | |
| Baltimore, MD | 6 | 0.04 | 0.01 | 0.09 |
| Cape May, NJ | 1 | 0.02 | -- | -- |
| Exmore, VA | 1 | 0.04 | -- | -- |
| Hampton Roads, VA | 2 | 0.05 | 0.03 | 0.07 |
| New York, NY | 3 | 0.06 | 0.04 | 0.08 |
| Philadelphia, PA | 5 | 0.03 | 0.02 | 0.04 |
| Montross, VA | 1 | 0.13 | -- | -- |
| Washington, DC | 2 | 0.04 | 0.02 | 0.06 |
| Total | 21 | 0.05 | 0.01 | 0.09 |
| **Butterfish** | | | | |
| Baltimore, MD | 2 | 0.05 | 0.03 | 0.07 |
| **Rockfish** | | | | |
| Washington, DC | 1 | ND* | -- | -- |
| **Clam** | | | | |
| Baltimore, MD | 1 | trace | -- | -- |
| Severn, VA | 4 | trace | ND | trace |
| Total | 5 | trace | ND | trace |
| **Trout** | | | | |
| Baltimore, MD | 5 | 0.05 | 0.02 | 0.07 |
| Halethorpe, MD | 1 | 0.02 | -- | -- |
| Philadelphia, PA | 1 | 0.04 | -- | -- |
| Severn, VA | 3 | 0.07 | 0.04 | 0.10 |
| Tangier, VA | 1 | 0.02 | -- | -- |
| Washington, DC | 2 | 0.01 | trace | 0.02 |
| Total | 14 | 0.04 | trace | 0.10 |

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*ND - None Detected.

Source: FDA (1977).

Table VII-17 (Concluded)

| Species/ Place of Collection | Sample | Kepone (ppm) Average | Minimum | Maximum |
|---|---|---|---|---|
| **Spot** | | | | |
| Baltimore, MD | 4 | 0.05 | 0.02 | 0.14 |
| Halethorpe, MD | 1 | 0.02 | -- | -- |
| Tangier, VA | 1 | 0.03 | -- | -- |
| Washington, DC | 2 | 0.01 | trace | 0.02 |
| Whitestone, VA | 1 | 0.03 | -- | -- |
| Total | 9 | 0.09 | trace | 0.14 |
| **Catfish** | | | | |
| Lanexa, VA | 1 | 0.02 | -- | -- |
| Smithfield, VA | 1 | 0.04 | -- | -- |
| Toano, VA | 5 | 0.05 | 0.02 | 0.08 |
| Washington, DC | 1 | trace | -- | -- |
| Total | 8 | 0.04 | trace | 0.08 |
| **Flounder** | | | | |
| Baltimore, MD | 2 | 0.01 | trace | 0.01 |
| Washington, DC | 2 | 0.01 | 0.01 | 0.01 |
| Total | 4 | 0.01 | trace | 0.01 |
| **Mackerel** | | | | |
| Baltimore, MD | 1 | 0.07 | -- | -- |
| Hampton, VA | 1 | 0.08 | -- | -- |
| Total | 2 | 0.07 | 0.07 | |
| **Crab** | | | | |
| Baltimore, MD | 3 | 0.10 | 0.01 | 0.28 |
| Crisfield, MD | 2 | trace | -- | -- |
| Hampton, VA | 2 | 0.25 | 0.20 | 0.29 |
| Hayes, VA | 1 | 0.03 | -- | -- |
| Newport News, VA | 4 | 0.03 | 0.01 | 0.04 |
| Total | 11 | 0.08 | trace | 0.29 |
| **Oyster** | | | | |
| Baltimore, MD | 2 | ND | | |
| Washington, DC | 2 | ND | | |
| Total | 4 | ND | | |

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All samples of the nine finfish species contained detectable levels of kepone, except for the single rockfish sample. The mean level of kepone in finfish was 0.038 ppm, with two samples of fish exceeding the 0.1 ppm action level. No clam or oyster samples contained residues greater than 0.02 ppm. Most contained undetectable levels. All crab samples contained detectable levels of kepone, but none of the samples exceeded the 4-ppm action level for crabs. The mean level of kepone in crabs was 0.08 ppm.

Table VII-18 compares the results of the FDA market place samples collected before the issuance of the Compliance Program with those collected under the program. For most of the species covered in both periods, the mean kepone levels were quite similar.

Data on concentrations of kepone in various species of finfish, shellfish, and crabs from the James River, Chesapeake Bay, and the marketplace were analyzed by Bender et al. (1977). The data were separated into categories: finfish, shellfish, and crabs. Within these categories the data were separated into species. Finfish species with fewer than 10 observations were grouped into a species labeled "other." The weighted average kepone concentrations, based on sample mass, that was calculated for each of the 42 cells is given in Table VII-19. These calculations are part of the "what if" program developed by VPI (Krutchkoff, 1977).

The EPA (1977) summarized the kepone concentration of a set of seafood samples taken from the Chesapeake Bay and the James River. For the Chesapeake Bay there were 193 finfish samples, representing 16 species. Excluding shad, the average concentration was 0.056 ppm with a range of 0 to 0.86 ppm; the average for the shad was 0.117 ppm. The 110 shellfish samples had an average concentration of 0.046 ppm, with a range of 0 to 0.76 ppm. The 48 crab samples had an average concentration of 0.261 ppm, with a range of 0 to 3.44 ppm.

For the James River, the 51 samples represented 10 species and showed an average concentration of 0.931 ppm, with a range of 0 to 8.1 ppm (no higher than for other finfish). The 55 shellfish samples had an average concentration of 0.209 and a range of 0 to 0.51 ppm. Only 5 crab

## Table VII-18

### COMPARISON OF KEPONE IN FISHERY PRODUCTS FROM MARYLAND AND VIRGINIA TAKEN BEFORE AND DURING THE FDA COMPLIANCE EVALUATION PROGRAM (CEP)

| | Sampling before CEP | | CEP Sampling | | Total | |
|---|---|---|---|---|---|---|
| Specie | No. of Samples | Mean (ppm) | No. of Samples | Mean (ppm) | No. of Samples | Mean (ppm) |
| Bluefish | 22 | 0.040 | 21 | 0.047 | 43 | 0.043 |
| Croaker | 20 | 0.032 | 21 | 0.033 | 41 | 0.033 |
| Crabs | 12 | 0.102 | 12 | 0.082 | 24 | 0.092 |
| Spot | 6 | 0.035 | 9 | 0.035 | 15 | 0.035 |
| Trout | 5 | 0.046 | 13 | 0.044 | 18 | 0.045 |
| Catfish | 6 | 0.007 | 8 | 0.037 | 14 | 0.024 |
| Rockfish | 1 | 0.080 | 1 | ND | 2 | 0.040 |
| Shad | 31 | 0.031 | — | | 31 | 0.031 |
| Eel | 1 | 0.030 | — | | 1 | 0.030 |
| Herring | 1 | ND* | -- | | 1 | ND |
| Perch | 1 | 0.070 | -- | | 1 | 0.070 |
| Mackerel | --† | | 2 | 0.075 | 2 | 0.075 |
| Flounder | — | | 4 | 0.010 | 4 | 0.010 |
| Butterfish | — | | 2 | 0.050 | 2 | 0.050 |
| Oysters | — | | 4 | ND | 4 | ND |
| Clams | — | | 5 | 0.008 | 5 | 0.008 |

---

*ND - None Detected.

†—No samples taken.

Source: FDA (1977).

Table VII-19

## ESTIMATED AVERAGE KEPONE CONCENTRATIONS IN JAMES RIVER AND CHESAPEAKE BAY FISH (PPM)

| Species | James River | Chesapeake Bay | Market |
|---|---|---|---|
| Black crappie | 1.0116 | -- | -- |
| Bluefish | 0.2859 | 0.0589 | 0.0485 |
| Butterfish | -- | 0.0629 | 0.0194 |
| Catfish | 0.0514 | -- | 0.0382 |
| Croaker | -- | 0.0411 | 0.0233 |
| Eel | 0.6415 | 0.0659 | -- |
| Flounder | -- | 0.0775 | 0.0159 |
| Herring | 0.2213 | 0.0310 | -- |
| Largemouth bass | 2.4158 | -- | -- |
| Mullet | -- | -- | 0.0743 |
| Perch | 2.6526 | 0.0617 | -- |
| Striped bass | 0.3822 | -- | -- |
| Shad | 0.0257 | 0.0172 | 0.0202 |
| Spot | 0.8157 | 0.0282 | 0.0211 |
| Trout | 0.1525 | 0.0725 | 0.0309 |
| Weakfish | -- | 0.0303 | -- |
| Other | 1.3772 | 0.0441 | 0.0556 |
| Clams and Conchs | 0.0486 | 0.0080 | -- |
| Oysters | 0.1429 | 0.0080 | -- |
| Crabs | 0.3405 | 0.0984 | 0.0911 |

Source: Bender et al. (1977).

samples were available; their concentration averaged 2.69 ppm and ranged from 2.04 to 3.10 ppm.

Restrictions on James River Seafood--As of April 1977, the James River has been opened for the taking of shad, herring, baby eel, turtles, all catfish, and shellfish; the lower James is open for taking female crabs, but their use is limited to the processing trade.

### 6. Kepone Concentrations in Spring Creek, Pennsylvania, Fish

As indicated in Section VII-A-4, kepone has been found in fish taken from Spring Creek near the Nease Chemical plant. Clista (1977) reports that trout and suckers taken within 18 mi downstream of the plant show kepone concentrations of 0.025 to 0.23 ppm. The Pesticide Chemical News (August 11, 1976) reported that kepone concentrations of 0.15 to 0.17 ppm had been found in trout, with 0.18 ppm in suckers.

### 7. Kepone in Chickens from Contaminated Fishmeal

Fish taken from Chesapeake Bay have been shown to be kepone-contaminated. Part of the catch is used to make fishmeal that is fed to chickens, but no data have been found to indicate the possible levels of contamination to chicken meat and eggs. In a test program, hens were fed 75- to 100-ppm kepone in their feed for 16 weeks. (Fish taken from Chesapeake Bay have shown average kepone concentrations on the order of 0.01 to 0.1 ppm, and fishmeal has shown concentrations of 0.02 to 0.06 ppm.) After 5 weeks of treatment, the kepone content of egg yolk was 163 and 336 ppm, respectively, for the two dosage levels. After 13 weeks it was 100 and 214 ppm, respectively; 3 weeks after kepone ingestion had ceased, kepone content was 26 and 70 ppm, respectively (Naber and Ware, 1965). Hence, chickens fed fishmeal contaminated at the 0.02 to 0.06 ppm level might be expected to produce eggs that were contaminated to that level or higher.

# VIII HUMAN EXPOSURE TO MIREX AND KEPONE THROUGH FOOD CONSUMPTION

## A. General

As Section VII has shown, the major foods contaminated by mirex and kepone are finfish, shellfish, and crustacea taken from selected areas in the eastern United States. Human exposure, therefore, depends on the amount of these foods taken from the contaminated areas and eaten by individuals.

Another contaminated food that can be of importance is mother's milk. About 3% of the samples evaluated have been found to be kepone-contaminated. This contamination may be of particular importance because of the latency of cancer development and because milk constitutes a substantial proportion of an infant's diet.

## B. Human Food Consumption

Various food consumption surveys indicate that the average person, depending on socioeconomic characteristics, might consume an average of from 10 to 40 g/day of fish. Considering the relatively high levels of mirex and kepone in fish taken from various locations and considering that certain individuals consume substantially more than the average rate, this exposure route can be important.

A major source of data concerning the consumption of fish product purchases (by socioeconomic characteristics of households) was obtained from a survey conducted in 1969-1970 by Market Facts, Inc. for the Bureau of Commercial Fisheries (Nash, 1970). In this survey, 1500 households maintained diaries of fish and shellfish purchases for more than a year. The participants were representative of the U.S. population by geographic region and included a wide variation of incomes, family sizes, occupations, and ages, as well as races and religions. The results of this survey are broken down in detail for 37 types of fish purchased during the year.

Tabulations of the average consumption of various types of purchased fish products, based on the Market Facts Survey, are presented in Table VIII-1. The results, which are given for the three major regions of interest for mirex and kepone exposure (New England, Middle Atlantic, and South Atlantic), as well as for the national average, represent average home consumption of pruchased fish. (Note that certain individuals consume much more fish than the average, and thus are potentially exposed to much higher levels of mirex and kepone than averages would indicate.) Finch (1973) states that the results of the Market Facts Survey show that 1.8% of the participants consumed an average of more than 60 g/day of fish and, in fact, 0.1% of the participants consumed more than 165 g/day. These estimates include sportscatch eaten at home and fish eaten away from home. These results have been used to estimate the consumption of purchased fish by various population percentiles. These are:

| Population Percentile | Fish Products (g/day) |
|---|---|
| 10.0 | 26.0 |
| 5.0 | 38.0 |
| 1.0 | 77.0 |
| 0.1 | 165.0 |

The consumption of nonpurchased (sport fish) has not been reported in the same detail for purchased fish. Based on a projection of the "U.S. Department of Agriculture Food Consumption Survey 1965-1966" (1972), we estimate the average total daily consumption of fish to be 21.6 g per person. This means that approximately 5.7 g of sportsfish and fish eaten away from home are consumed per person per day. According to La Bovit (1970), 20% of fish consumption occurs away from home. Miller and Nash (1971) show that the fish purchased for eating away from home are generally lobsters, clams, shrimp, oysters, halibut, flounder, and haddock.

Another segment of the population expected to consume above average quantities of fish are people belonging to Weightwatchers or on special diets that substitute fish for other meat. The Weightwatchers diet follows (Weightwatchers Handbook, 1974):

Table VIII-1

U.S. PURCHASED FISH CONSUMPTION
(g/day)

| Seafood Type | Average U.S. | New England | Middle Atlantic | South Atlantic |
|---|---|---|---|---|
| Specialty items | | | | |
| Tuna pie | 0.168 | 0.167 | 0.154 | 0.096 |
| Clam chowder | 0.293 | 0.687 | 0.488 | 0.390 |
| Oyster stew | 0.171 | 0.153 | 0.216 | 0.216 |
| TV dinners | 0.560 | 0.583 | 0.722 | 0.436 |
| Smoked fish | 0.137 | 0.092 | 0.196 | 0.103 |
| Other specialties | 0.415 | 0.728 | 0.656 | 0.442 |
| Shellfish | | | | |
| Shrimp | 1.200 | 1.240 | 1.562 | 1.557 |
| Oysters | 0.254 | 0.155 | 0.144 | 0.507 |
| Crab | 0.196 | 0.200 | 0.157 | 0.265 |
| Lobsters | 0.214 | 2.355 | 0.142 | 0.175 |
| Lobster tails | 0.168 | 0.065 | 0.262 | 0.108 |
| Clams | 0.094 | 0.807 | 0.091 | 0.043 |
| Scallops | 0.107 | 0.342 | 0.163 | 0.070 |
| Other shellfish | 0.010 | 0.011 | 0.004 | 0.011 |
| Finfish | | | | |
| Haddock | 0.740 | 2.375 | 1.235 | 0.707 |
| Flounder | 0.682 | 0.768 | 1.507 | 0.999 |
| Halibut | 0.390 | 0.373 | 0.306 | 0.068 |
| Ocean perch | 0.779 | 0.142 | 0.403 | 1.232 |
| Cod | 0.700 | 0.984 | 0.936 | 0.764 |
| Salmon | 0.213 | 0.155 | 0.102 | 0.088 |
| Red snapper | 0.210 | 0.022 | 0.154 | 0.129 |
| Catfish | 0.317 | 0.000 | 0.000 | 0.190 |
| Whiting | 0.239 | 0.179 | 0.213 | 0.403 |
| Swordfish | 0.209 | 1.527 | 0.293 | 0.065 |
| Pollock | 0.019 | 0.056 | 0.015 | 0.027 |
| Other finfish | 0.840 | 0.629 | 0.613 | 2.007 |
| Canned fish | | | | |
| Salmon | 1.813 | 1.092 | 1.767 | 2.024 |
| Tuna | 3.601 | 4.722 | 4.102 | 3.174 |
| Sardines | 0.437 | 0.373 | 0.584 | 0.838 |
| Shrimp | 0.188 | 0.410 | 0.205 | 0.085 |
| Oysters | 0.227 | 0.034 | 0.088 | 0.281 |
| Other canned | 0.200 | 0.424 | 0.283 | 0.170 |
| Total | 15.9 | 21.883 | 17.763 | 17.671 |

---

Source: Nash (1970).

| Seafood Type | Grams per Day |
|---|---|
| Shrimp | 16.3 |
| Salmon | 16.3 |
| Scallops | 16.3 |
| Tuna | 16.3 |
| Other fish | 32.6 |
| Total fish | 97.8 |

Of the approximately 8 million people who subscribe to the Weightwatchers program, it is now known how may adhere to the prescribed diet.

The amounts of all food consumed per capita is found to vary within the general population, primarily as a function of sex and age. Socio-economic variables such as income status are also found to be associated with food consumption.

## C. Human Consumption of Mirex in Foods

### 1. Potential Mirex Exposure from Lake Ontario Fish

Lake Ontario is currently closed to the taking of many species of fish because of mirex contamination. This does not mean that the lake will permanently remain closed; however, because of the environmental persistance of mirex, fish taken from the lake are expected to be contaminated for some time to come. Moreover, the lake has not been closed to Canadian fishing (except for commercial fishing of coho and chinook salmon) or the marketing of Canadian catches. The potential exposures listed here indicate possible exposures if the lake is reopened or if sportsfishermen disregard the restrictions.

The eastern basin of Lake Ontario provides almost all sports fishing and most of the commercial fishing in the lake (Great Lakes Basin Commission, 1975). Sports fishing, which has been a major factor in the economy of many communities near the lake, is estimated to have amounted to 8.8 million angler days in 1970 (Great Lakes Basin Commission, 1975). Sports fishing has basically consisted of open-water fishing, fishing for bass, and shore fishing for bullheads, smelt, and native finfish.

## Table VIII-2

## U.S. PER CAPITA FOOD CONSUMPTION
(g/day)

| | Male[*] 19 | Infant[†] 1 year | Male[†] 15-17 | Female[†] 15-17 | Male[†] 35-54 | U.S.[‡] Average |
|---|---|---|---|---|---|---|
| Dairy products | 880 | 800 | 700 | 480 | 280 | 440 |
| Meat, fish, poultry | 214 | 50 | 275 | 200 | 300 | 322 |
| Grain and cereal products | 437 | 25 | 137 | 87 | 112 | 202 |
| Potatoes | 187 | 5 | 90 | 50 | 75 | 168 |
| Vegetables | 272 | 13 | 75 | 75 | 78 | 198 |
| Leafy | 46 | -- | -- | -- | -- | -- |
| Legume | 67 | -- | -- | -- | -- | -- |
| Root | 159 | -- | -- | -- | -- | -- |
| Fruit | 291 | 17 | 100 | 80 | 100 | 161 |
| Oils, sugars, etc. | 138 | 12 | 98 | 63 | 85 | 86 |
| Oils, fats, shortening | 69 | -- | -- | -- | -- | -- |
| Sugar and adjuncts | 69 | -- | -- | -- | -- | -- |
| Beverages | 1202 | 6 | 420 | 390 | 950 | 500 |

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[*] Lang et al. (1963).

[†] USDA (1972).

[‡] Statistical Abstracts (1975).

Commercial fishing landings for 1973 and 1974 are given in Table VIII-3 for the United States and Canada. The U.S. fish catch was about 300,000 lb annually, and the Canadian total was about eight times higher. No data have been found that indicate where the Lake Ontario commercial catch has been marketed nor the amount of sports fish caught.

Table VIII-4 shows the proportion of fish in the 1974 U.S. commercial catch by species taken from the lake and the average mirex concentrations found in the fish. If it is assumed that a person eats fish species in the same proportion as the commercial catch, the weighted average mirex concentration is 0.057 ppm.

Table VIII-5 shows estimates of mirex consumption from Lake Ontario fish. These concentrations would result in an average intake of 0.34 μg/day of mirex for people taking all of their finfish from the lake. If a person's entire seafood component of his or her diet were taken from the lake, the mirex exposure would be 1.01 μg/day. Those eating the most fish (upper 10% of the consuming population) would consume 0.49 to 1.5 μg/day of mirex or less, depending on the amount of seafood in the diet taken from locations other than Lake Ontario. (Most people would supplement Lake Ontario finfish in their diet with fish taken from other locations.) Based on the average amount of freshwater fish consumed, the estimated exposure would be 0.05 μg/day.

The 1970 population of counties bordering Lake Ontario was 1.3 million; population within a two-county distance from the lake was 3.4 million. Because about 14% of the U.S. population fishes for freshwater fish (FDA, 1976), these population figures would indicate about 480 thousand local fishermen. Because each of these would fish for one or more people, about 500,000 to 1 million local people might eat some Lake Ontario fish.

Another approach to estimating the size of the population at risk is based on the size of the commercial catch. According to Table VIII-3, the 1974 U.S. commercial catch from Lake Ontario was 324,000 lb. If it is assumed that one-third of the live weight of finfish is edible (Thorslund and O'Mara, 1977) and that an average per capita mid-Atlantic

## Table VIII-3

## COMMERCIAL FISHERIES LANDING FOR LAKE ONTARIO (1b in 1000s)

| Species | United States | | Canada | | Total | |
|---|---|---|---|---|---|---|
| | 1973 | 1974 | 1973 | 1974 | 1973 | 1974 |
| Bowfin | 1 | -- | 4 | 5 | 5 | 5 |
| Bullheads | 53 | 73 | 233 | 248 | 286 | 321 |
| Carp | 19 | 16 | 413 | 395 | 432 | 411 |
| Catfish | 2 | 4 | 24 | 24 | 26 | 28 |
| Crappie | 9 | 7 | -- | 14 | 9 | 21 |
| Eels, common | 40 | 51 | 188 | 222 | 228 | 273 |
| Lake herring | 1 | <1 | 17 | 32 | 18 | 32 |
| Lake trout | -- | -- | <1 | 1 | <1 | 1 |
| Pike or pickerel | -- | <1 | 11 | 21 | 11 | 21 |
| Rock bass | 22 | 14 | 44 | 28 | 66 | 42 |
| Sauger | -- | -- | <1 | -- | <1 | -- |
| Sheepshead | <1 | 1 | 6 | 4 | 6 | 5 |
| Smelt | 5 | 7 | 99 | 103 | 104 | 110 |
| Sturgeon | <1 | -- | 1 | 1 | 1 | 1 |
| Suckers | 8 | 6 | 18 | 15 | 26 | 21 |
| Sunfish | 19 | 14 | 208 | 204 | 227 | 218 |
| White bass | 2 | <1 | 6 | 4 | 8 | 4 |
| Whitefish | <1 | <1 | 16 | 16 | 16 | 16 |
| White perch | 54 | 81 | 287 | 290 | 341 | 371 |
| Yellow perch | 64 | 49 | 757 | 699 | 821 | 748 |
| Yellow pike | 1 | 1 | 4 | 3 | 5 | 4 |
| Unclassified for animal food | -- | -- | 20 | 35 | 20 | 35 |
| Total | 300 | 324 | 2,356 | 2,364 | 2,656 | 2,688 |

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Source: 1973 data - Pileggi and Thompson (1976).
1974 data - National Marine Fisheries (1976).

## Table VIII-4

## PROPORTION BY SPECIES IN U.S. COMMERCIAL CATCH FOR LAKE ONTARIO, 1974

| Species | Proportion in Catch | Mirex Concentrations (ppm) |
|---|---|---|
| Bullheads | 0.2253 | 0.03 |
| Carp | 0.0494 | 0.02 |
| Catfish | 0.0123 | 0.27 |
| Crappie | 0.0216 | 0.01 |
| Eels, common | 0.1574 | 0.05 |
| Lake herring | 0.0031 | ND* |
| Pike or pickerel | 0.0031 | 0.03 |
| Rock bass | 0.0432 | 0.03 |
| Sheepshead | 0.0031 | NR† |
| Smelt | 0.0216 | 0.13 |
| Suckers | 0.0185 | 0.02 |
| Sunfish | 0.0432 | NR |
| White bass | 0.0031 | 0.05 |
| Whitefish | 0.0031 | NR |
| White perch | 0.2500 | 0.09 |
| Yellow perch | 0.1512 | 0.05 |
| Yellow pike | 0.0031 | 0.06 |

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[*] ND - None Detected.

[†] NR - Not Reported.

finfish consumption of 5.777 g/day (Nash, 1970), the 1974 commercial catch supplied the annual diet of finfish for 70,000 people. (This estimated population is for the commercial catch only.)

Table VIII-5

ESTIMATED POTENTIAL DAILY PER CAPITA INTAKE OF MIREX FOR CONSUMERS OF LAKE ONTARIO FISH

| Percent of Consuming Population | Assuming all Finfish in Diet Taken from Lake[†] (μg/day) | Assuming all Seafood in Diet Taken from Lake (μg/day) |
|---|---|---|
| Average[*] | 0.335 | 1.014 |
| 10 | 0.490 | 1.484 |
| 5 | 0.716 | 2.169 |
| 1 | 1.451 | 4.395 |
| 0.1 | 3.146 | 9.532 |

---

[*] Assumes 5.777 g/day of finfish eaten and 17.763 g/day of all seafood eaten.

[†] That is, 33% of the seafood in the diet is finfish.

## 2. Mirex Exposure from St. Lawrence Fish

Estimated human mirex exposures for the consumption of St. Lawrence fish are given in Table VIII-6. Two sets of exposures are given: one assumes that all finfish eaten by a consumer are taken from the river and the other assumes that all seafood eaten by a consumer are taken from the river. Average daily per capita mirex consumptions for the two sets of exposure assumptions are 0.39 and 1.17 μg, respectively. Based on the average amount of freshwater fish consumed, the exposure would be 0.06 μg/day. The size of the consuming population is not known; most of the target population, however, would live near the St. Lawrence river and might supplement part of their diet with sportscatch of fish from the river. These people might also consume some seafood from Lake Ontario.

Table VIII-6

### ESTIMATED DAILY PER CAPITA INTAKE OF MIREX FOR CONSUMERS OF ST. LAWRENCE FISH

| Percent of Consuming Population | Assuming all Finfish in Diet Taken from River† (μg/day) | Assuming all Seafood in Diet Taken from River (μg/day) |
|---|---|---|
| Average* | 0.387 | 1.172 |
| 10 | 0.566 | 1.716 |
| 5 | 0.828 | 2.508 |
| 1 | 1.677 | 5.082 |
| 0.1 | 3.637 | 11.022 |

---

*Assumes 5.777 g/day of finfish eaten and 17.763 g/day of all seafood eaten.

†That is, 33% of the seafood in the diet is finfish.

According to the 1970 population, there were 200,500 people residing in counties bordering on the St. Lawrence River. Population within a two-county distance from the river was 377,600. Given that about 14% of the U.S. population freshwater fishes (FDA, 1976), there are about 53,000 local fishermen. Each of these would fish for one or more people giving a local at-risk population estimate of about 50,000 to 100,000. The amount of fish taken from the St. Lawrence and eaten by many of these people would be minimal.

### 3. Mirex Exposure from Spring Creek, Pennsylvania, Fish

Characterizing the consumption of mirex from fish taken from Spring Creek is complicated because the extent of contamination of fish in the creek or the extent of fishing on the creek have not been reported. The creek has been said to be a good spot for sportsfishing, but apparently it has no commercial fishing. Mirex concentrations of 0.02 to 1.0 ppm have been found in suckers and trout taken near the

NEASE chemical plant. These concentrations could result in a mirex intake of 0.12 to 5.8 μg/day if an average consumer filled the entire finfish component of his diet with fish taken from Spring Creek. The intake could be 0.36 to 17.8 μg/day if the average person's entire seafood supply came from Spring Creek. Based on the average amount of freshwater fish consumed, the average exposure would be 0.02 to 0.09 μg/day.

These exposures would only be applicable to, at most, a relatively few sportsmen who reside in the local area, and even these sportsmen would probably supplement their diet with seafood taken from other locations.

The Spring Creek fish are also kepone-contaminated; hence, the consumer would be exposed to both mirex and kepone.

### 4. Mirex Exposure to Residents of the Southeastern United States From Fish Consumption

A number of investigators* have recorded the mirex concentrations in fish taken from areas in the southeastern states where mirex bait has been applied. Specifically, mirex has been found in fish taken from Alabama, Arkansas, Georgia, Louisiana, Mississippi, and South Carolina. In general, higher concentrations of mirex have been found in fish taken from treated areas within a state than in fish taken from untreated areas within the same state. Moreover, concentrations are much higher shortly after application than they are several years after application. However, sampling tends to indicate that average concentrations on the order of 0.01 to 0.03 ppm in finfish will persist at least for several years after application. This is substantiated by the samples taken 1 to 2 years after application reported by Borthwich et al. (1974), Hawthorne et al. (1974b), and Collins et al. (1974). The 1976 sampling reported by the FDA (1977) showed detectable mirex concentrations in

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*See for example: FDA (1977), Markin et al. (1972b), Markin (1974), Borthwich et al. (1973), Borthwich et al. (1974), Baetche et al. (1972, Hawthorne et al. (1974b), Collins et al. (1974), and Wolfe and Norment (1973).

**finfish taken in Alabama, Arkansas, Louisiana, and Mississippi; mirex was not found in samples taken in Texas.**

Possible population exposures to southeastern U.S. residents from eating mirex contaminated fish are shown in Table VIII-7. These exposures assume that the average mirex concentration is 0.02 ppm for the eaten fraction of the mirex-contaminated fish. Based on available data, this average concentration appears to be appropriate. One difficulty lies in assessing the proportion of contaminated fish taken for food in the states. Assuming that all fresh and frozen finfish in an average person's diet are contaminated, the exposure would be 0.13 μg/day. The highest exposure illustrated in Table VIII-7 would be for the upper 0.1 percentile of fish consumers taking all of their seafood from contaminated areas. Their exposure would be 3.3 μg/day of mirex. Based on the average amount of freshwater fish consumed, the average exposure would be 0.02 μg/day.

The greatest mirex exposure is to sports fishermen in these areas. In addition, some commercial fishing takes place in the inland waters in these areas. Table VIII-8 lists the 1973 commercial catch for the Mississippi River, its tributaries, and other river systems draining into the Gulf of Mexico. For Alabama, Arkansas, Mississippi, and Louisiana more than 31 million lb of commercial catch were taken in 1973; of this amount about 25 million lb were finfish. This commercial catch of finfish would satisfy the finfish component of the diet for about 1.5 million people.

Much of the population of all the southeastern states in which mirex bait has been applied is probably ingesting some mirex with their fish. For most of these people, however, the mirex ingested is expected to be much less than the exposures listed in Table VIII-7. The 1970 total populations for these "at-risk" states are:

## Table VIII-7

## MIREX CONSUMPTION FROM FISH EATEN BY SELECTED RESIDENTS OF SOUTHEASTERN STATES (μg/day)

| Human Population Fish Consumption Percentile Based on Amount Eaten[*] | Percent of Fish in Standard Diet Taken from Contaminated Areas[†] | | |
|---|---|---|---|
| | 10% | 38%[‡] | 100% |
| Average | 0.04 | 0.13 | 0.35 |
| 10 | 0.05 | 0.20 | 0.52 |
| 5 | 0.08 | 0.29 | 0.76 |
| 1 | 0.15 | 0.59 | 1.54 |
| 0.1 | 0.33 | 1.25 | 3.30 |

---

[*] Total amounts eaten (g/day) for the various percentiles are assumed as 17.7, 26, 38, 77, and 165, respectively.

[†] Assumes an average mirex concentration of 0.02 ppm.

[‡] An average of 38% of the total seafood diet is composed of fresh and frozen finfish.

## Table VIII-8

## 1973 COMMERCIAL LANDINGS OF FISH AND SHELLFISH FOR THE MISSISSIPPI RIVER, ITS TRIBUTARIES, AND OTHER RIVER SYSTEMS DRAINING INTO THE GULF OF MEXICO

| Species | Landings (lb in 1000s) | | | | |
|---|---|---|---|---|---|
| | Alabama | Arkansas | Louisiana | Mississippi | Texas |
| Bowfin | -- | 85 | 44 | -- | 1 |
| Buffalo fish | 1,305 | 7,426 | 1,907 | 910 | 2,336 |
| Carp | 375 | 628 | 156 | 1,431 | 310 |
| Catfish and bullheads | 796 | 3,050 | 1,801 | 537 | 336 |
| Chubs | -- | -- | 308 | -- | -- |
| Mooneye or goldeye | -- | -- | -- | 150 | -- |
| Garfish | 15 | 169 | -- | -- | 41 |
| Gizzard shad | 67 | -- | 18 | -- | -- |
| Paddlefish | 89 | 126 | -- | -- | 1 |
| Quillback | -- | 138 | 1,200 | 51 | -- |
| White bass | -- | -- | -- | 39 | -- |
| Sheepshead | 160 | 714 | 850 | 18 | 40 |
| Sturgeon, shovelnose | -- | 1 | -- | -- | -- |
| Suckers | -- | 75 | -- | 15 | -- |
| Sunfish | -- | -- | -- | -- | 2 |
| Total Finfish | 2,807 | 12,412 | 6,284 | 3,151 | 3,097 |
| Mussel shells | 208 | 595 | -- | -- | -- |
| Turtles: | | | | | |
| Snapper | -- | 16 | 80 | -- | -- |
| Soft-shell | -- | 1 | -- | -- | -- |
| Crawfish | -- | -- | 5,832 | -- | -- |
| Shrimp | -- | -- | 5 | -- | -- |
| Frogs | -- | -- | 29 | -- | -- |
| Total Shellfish | 208 | 612 | 5,946 | -- | -- |
| Grand Total | 3,015 | 13,024 | 12,230 | 3,151 | 3,097 |

Source: Pileggi and Thompson (1976).

| State | 1970 Population |
|---|---|
| Alabama | 3,444,165 |
| Arkansas | 1,923,295 |
| Georgia | 4,589,575 |
| Mississippi | 2,216,912 |
| Texas | 11,196,730 |
| Florida | 6,789,443 |
| South Carolina | 2,590,516 |

About 14% of the U.S. population did some freshwater fishing during 1970 (FDA, 1976). For Alabama, Arkansas, Georgia, Louisiana, Mississippi, and South Carolina this represents an estimated 2 million fishermen. The at-risk population to eating at least some sportsfish caught in these states would be 2 to 4 million because many families tend to fish together and because many of the fishermen indicated might go fishing less than twice per year.

## D. Kepone Exposure from Fish Consumption

### 1. Kepone Exposure from Chesapeake Bay and James River Fish

The lower James River is currently closed for the taking of most fish. Chesapeake Bay is not closed, but commercial catches are monitored to determine if the kepone concentrations are below action levels.

The Chesapeake Bay, its tributaries, and nearby areas of the Atlantic Ocean have been active areas for commercial fishing. Table VIII-9 gives the catches by species for 1974 and 1975. Each year about 230 million lb of fish products have been commercially taken from these waters.

Thorslund and O'Mara (1977) estimated the 1975 commercial fishing catch for the Chesapeake Bay and its tributaries in terms of edible pounds by species (Table VIII-10). For the entire Bay approximately 50 million lb of edible seafood products were produced from commercial and sports fishing. Oysters make up approximately one-third of this weight.

Table VIII-9

COMMERCIAL FISHERIES LANDINGS FOR THE CHESAPEAKE BAY, ITS TRIBUTARIES, AND NEARBY AREAS OF THE ATLANTIC OCEAN (1b in 1000s)

| Species | Maryland | | Virginia | | Total | |
|---|---|---|---|---|---|---|
| | 1974 | 1975 | 1974 | 1975 | 1947 | 1975 |
| **Finfish** | | | | | | |
| Bluefish | 574.8 | 270.9 | 3,137.3 | 3,284.9 | 3,712.1 | 3,555.8 |
| Striped bass | 3,567.0 | 2,722.2 | 2,564.2 | 1,329.1 | 6,131.2 | 4,051.3 |
| Grey trout | 411.8 | 891.8 | 3,062.9 | 4,089.8 | 3,474.7 | 4,981.6 |
| Croakers | 120.4 | 639.1 | 1,501.9 | 4,720.9 | 1,622.3 | 5,360.0 |
| All other | 2,488.6 | 3,192.9 | 12,235.0 | 13,424.7 | 14,723.6 | 16,617.6 |
| Total | 7,162.6 | 7,716.9 | 22,501.3 | 25,876.4 | 29,663.9 | 33,593.3 |
| **Shellfish** | | | | | | |
| Crabs | 26,483.0 | 25,900.0 | 41,633.2 | 35,562.0 | 68.146.2 | 61,462.0 |
| Oysters | 18,284.0 | 15,953.5 | 6,737.7 | 5,544.0 | 25,021.7 | 21,497.5 |
| All other | 7,859.8 | 6,755.8 | 62,374.6 | 43,008.8 | 70,234.4 | 49,764.6 |
| Total | 52,626.8 | 48,609.3 | 110,774.9 | 84,114.8 | 163,401.7 | 132,724.1 |
| Unclassified | -- | -- | 4,377.8 | 6,825.6 | 4,377.8 | 6,825.6 |
| Nonfood fish | 7,638.2 | 7,194.9 | 34,576.2 | 48,106.5 | 42,214.4 | 55,301.4 |
| Grand Total | 67,430.5 | 63,524.5 | 172,230.2 | 164,923.3 | 239,660.7 | 228,447.8 |

Source: National Oceanic and Atmospheric Association (1976a) and (1976b).

## Table VIII-10

## TOTAL CATCH AND ESTIMATED CONSUMPTION OF SEAFOOD FROM THE CHESAPEAKE BAY AND ITS TRIBUTARIES, 1975[*]

| Food Fish | Catch--Live Weight (lb) | Consumption--Edible Weight (lb) |
|---|---|---|
| Commercial Catch | | |
| Bluefish | 2,312,012 | 770,670 |
| Croaker | 2,872,204 | 957,402 |
| Flounder | 341,520 | 113,840 |
| Grey trout | 2,710,513 | 903,504 |
| Shad | 1,646,019 | 548,673 |
| Striped Bass | 2,107,398 | 702,623 |
| All other finfish | 6,706,200 | 2,235,400 |
| Total Finfish | 18,695,866 | 6,232,112 |
| Blue crabs | 47,541,907 | 4,754,191 |
| Oysters (meat) | 17,051,548 | 17,051,548 |
| Clams (meat) | 1,246,817 | 1,246,817 |
| Total Shellfish | 65,840,272 | 23,052,556 |
| Sportsfish Catch | | |
| Finfish | 60,013,000 | 20,005,000 |
| Shellfish | 3,822,830 | 1,109,240 |
| Nonfood Fish | | |
| Manhaden and alewives | 32,795,486 | 6,888,692 |

---

[*] Based on data given by Thorslund and O'Mara (1977); Potomac River catch excluded.

The National Marine Fisheries Service (NOAA) surveyed marine recreational fishing in the Northeastern United States for 1974; Maryland and Virginia were also included. Data on sportsfish catch were obtained by telephone, mail, and household surveys. For each state the following species were separated: bluefish, white perch, striped bass, spot, and weakfish; other categories included all other finfish, hardshell clams, oysters, and crabs. Approximately 87.5% of the catch was from Chesapeake Bay. The survey provided the following percentages (Thorslund and O'Mara, 1977):

| Species of Fish | Percent of Total Finfish by Weight |
|---|---|
| Bluefish | 47 |
| White perch | 9 |
| Striped bass | 10 |
| Spot | 5 |
| Weakfish | 8 |
| All other | 21 |

Because the percentage breakdown of weights for shellfish was unavailable, it was assumed that crabs made up 80% of the shellfish, and oysters and clams each accounted for 10% (Thorslund and O'Mara, 1977). Using these percentages, the estimated sportsfishing catch by species is given in Table VIII-11.

Note that the sportsfishing catch of finfish is approximately three times the commercial catch, whereas the commercial shellfish catch is approximately 17 times the sportsfishing catch.

As part of the "What If" kepone program, Krutchkoff (1977) estimated the proportional weights of fish in catches by species (Table VIII-12). He assumed that the weight of species taken for consumption follows the same proportion as the weight of samples taken for kepone evaluation. These proportions were then used in evaluations to characterize the consumption of kepone from seafood (Bender, 1977; Bender et al., 1977).

Table VIII-11

## ESTIMATED SPORTSFISH CATCH BY SPECIES FOR THE CHESAPEAKE BAY AND ITS TRIBUTARIES DURING 1974

| Species | Catch Weight (lb) | Edible Weight (lb) |
|---|---|---|
| Bluefish | 28,206,110 | 9,402,350 |
| White perch | 5,401,170 | 1,800,450 |
| Striped bass | 6,001,300 | 2,000,500 |
| Spot | 3,000,650 | 1,000,250 |
| Weakfish | 4,801,040 | 1,600,400 |
| All other finfish | 12,602,730 | 4,201,050 |
| Finfish Total | 60,013,000 | 20,005,000 |
| Clams | 382,283 | 110,930 |
| Oysters | 382,283 | 110,930 |
| Crabs | 3,058,264 | 887,440 |
| Shellfish Total | 3,822,830 | 1,109,300 |
| Grand Total | | 21,114,300 |

---

Based on data given by Thorslund and O'Mara (1977).

Table VIII-12

ESTIMATED PROPORTION IN CATCH BY SPECIES
FOR JAMES RIVER AND CHESAPEAKE BAY*

| Species | James River | Chesapeake Bay | Market |
|---|---|---|---|
| Black crappie | -- | -- | -- |
| Bluefish | 0.0047 | 0.1068 | 0.1106 |
| Butterfish | -- | 0.0038 | 0.0276 |
| Catfish | 0.6339 |  | 0.0316 |
| Croaker | -- | 0.1116 | 0.1920 |
| Eel | 0.0595 | 0.0426 | -- |
| Flounder | -- | 0.0156 | 0.0790 |
| Herring | -- | 0.3745 | -- |
| Largemouth bass | -- | -- | -- |
| Mullet | -- | -- | 0.0413 |
| Perch | 0.0017 | 0.0061 |  |
| Striped bass | 0.0056 | -- | -- |
| Shad | 0.2648 | 0.0404 | 0.0243 |
| Spot | 0.0002 | 0.0616 | 0.1288 |
| Trout | 0.0007 | 0.1182 | 0.0778 |
| Weakfish | -- | -- | 0.2868 |
| Others | 0.0289 | 0.1188 | -- |
| Clams | 0.4790 | 0.2680 | -- |
| Oysters | 0.5210 | 0.7320 | -- |
| Crabs | -- | -- | -- |

---

Source: Bender, et al. (1977).

*Based on proportional weights in samples used for kepone analysis.

Combining the commercial and sportsfishing catch for the region and dividing by the total catch weight give another estimate of the proportion consumed by species. This estimate is given in Table VIII-13.

### a. Estimated Kepone Exposures

The "What If" program is a computer model designed to answer questions regarding the possible human consumption of kepone from the ingestion of finfish, shellfish, and crabs taken from the James River and Chesapeake Bay. The program has a fixed data set that can be varied to answer various what if type questions that might be raised by researchers or decision makers. Kepone concentration and consumption data were each arrayed in 42 sets. These 42 sets are based on collection location (James River, Chesapeake Bay, and the market) and on species. The concentration and proportion of fish consumed by species data have been given in Tables VII-19 and VIII-12 (see Kurtchkoff, 1977; Bender, 1977; and Bender et al., 1977).

Each set of data was fit to statistical distribution functions. A good fit was found by using the exponential distribution. This distribution is useful because it can be completely characterized by one parameter (the mean). It was assumed that the distribution of edible meat in the sample represents the distribution of edible meat to the consumer (e.g., that the proportion of samples at a particular location in the James reflects the proportion of fish caught at that location).

The consumption levels of finfish (6.3 g/day), shellfish (2.6 g/day), and crabs (0.3 g/day) used in the program are average amounts of fresh and frozen purchased food determined by the Marketfacts Survey (Nash, 1970) for South Atlantic states.

The program can also vary the action levels of kepone concentration to determine human exposure. This part of the program apparently assumes that all products exceeding the action level would be detected and not marketed.

## Table VIII-13

## ESTIMATED CONSUMPTION OF CHESAPEAKE BAY SEAFOOD BY SPECIES
(Commercial and Sports Catch Combined)

| Species | Total Edible Weight (lb) | Proportion |
|---|---|---|
| Bluefish | 10,173,020 | 0.388 |
| White perch | 1,800,450* | 0.069 |
| Striped bass | 2,703,123 | 0.103 |
| Spot | 1,000,250* | 0.038 |
| Weakfish | 1,600,400* | 0.061 |
| All other finfish | 6,436,450 | 0.245 |
| Finfish Total | 26,237,112 | 1.000 |
| | | |
| Clams | 1,357,747 | 0.056 |
| Oysters | 17,162,478 | 0.710 |
| Crabs | 5,641,631 | 0.233 |
| Shellfish Total | 24,161,856 | 1.000 |

---

*Sportsfishing catch only.

Table VIII-14 gives estimated daily kepone intake (assuming that there is no action level) for consumption of James River and Chesapeake Bay finfish, shellfish, and crabs. The six sets of exposure estimates given for each source location are based on three consumption levels and on two levels of kepone contamination (average values and the contamination for the higher 1% of fish). The three consumption levels are:

- The average consumption for the South Atlantic states.
- The level roughly corresponding to the total seafood consumed by 10% of the population but using the same distribution of species consumed by the average population.
- Levels roughly corresponding to the total seafood consumed by 10% of the population but assuming the diet is 59% finfish, 17% shellfish, and 24% oysters.

Based on these results, which are summarized from the "What If" program, it is concluded that the average person eating seafood from the Bay or from both the James and the Bay will consume 0.3 to 0.4 μg/day of kepone. People in the upper 10% of the seafood consuming population ingest 1.0 to 1.6 μg/day of kepone on the average. People who consume only James River fish have an average kepone intake of 1.1 μg/day, with an upper 10% limit based on consumption of 3.5 μg/day.

Those few who might eat only fish that have high kepone contaminations (i.e., contaminations in the upper 1% level of all fish analyzed) would consume one-fourth to one-half again as much kepone as do consumers of average concentrations.

The kepone consumption levels reported in Table VIII-14 may be high for most consumers. People residing in the James River and Chesapeake Bay area would most likely include seafood in their diet that, although the species are found in the James or the Bay, is taken from nonkepone-contaminated locations. On the other hand, the kepone consumption estimates are low for people who might eat seafood taken only from the James or the Bay. The kepone consumption for these people has been estimated using the following assumptions:

Table VIII-14

## YEARLY AVERAGE KEPONE INTAKE PER DAY FOR CONSUMPTION OF FINFISH, SHELLFISH, AND CRABS TAKEN FROM CHESAPEAKE BAY AND JAMES RIVER (μ/g)

| Source of Fish | Yearly Consumption (lb) | Average Kepone Intake (μg/day) | Kepone Intake <0.01%[§] (μg/day) |
|---|---|---|---|
| James River | 7.4[*] | 1.1 | 1.6 |
| | 23.2[†] | 3.5 | 5.1 |
| | 23.2[‡] | 4.9 | 6.4 |
| Chesapeake Bay | 7.4[*] | 0.3 | 0.4 |
| | 23.2[†] | 1.0 | 1.2 |
| | 23.2[‡] | 1.5 | 1.7 |
| James and Bay | 7.4[*] | 0.4 | 0.5 |
| | 23.2[†] | 1.2 | 1.6 |
| | 23.2[‡] | 1.6 | 2.0 |
| Market | 7.4[*] | 0.3 | 0.4 |
| | 23.2[†] | 1.0 | 1.2 |
| | 23.2[‡] | 1.4 | 1.6 |

---

Source: Bender et al., (1977) and based on an unlimited action level.

[*] Equivalent of 9.2 g/day (6.2 g finfish, 2.6 g shellfish, and 0.3 g oysters).

[†] Equivalent of 28.8 g/day (19.8 g finfish, 8.2 g shellfish, and 0.9 g oysters).

[‡] Equivalent of 28.8 g/day (17 g finfish, 5 g shellfish, and 7 g oysters).

[§] Kepone concentration for the upper 1% of the catch.

- Seafood species of finfish and of shellfish are eaten in the same proportion as the catch (Table VIII-13).
- Finfish and shellfish are eaten in the same proportions as found in the Marketfacts Survey (Table VIII-1).
- Kepone concentrations are the same as those used in the "What If" program (Table VII-19).
- Weights of seafood eaten for different fractions of the population are in accordance with data given by Finch (1973).

Use of these assumptions results in the estimated average daily intake of kepone given in Table VIII-15. The average consumer, eating only seafood from Chesapeake Bay or the James River would ingest 3.5 and 8.5 μg/day of kepone, respectively.

Table VIII-15

DAILY AVERAGE KEPONE INTAKE OF KEPONE FOR CONSUMERS WHO TAKE THEIR ENTIRE DIET OF SEAFOOD FROM THE CHESAPEAKE BAY OR JAMES RIVER

| Percent of Population Group* | Seafood Consumption (g/day) | Kepone Consumption (μg/day) | |
|---|---|---|---|
| | | Chesapeake Bay | James River‡ |
| Average† | 14.2 | 3.5 | 8.5 |
| 10.0 | 26.0 | 6.4 | 15.5 |
| 5.0 | 38.0 | 9.4 | 22.6 |
| 1.0 | 77.0 | 19.0 | 45.8 |
| 0.1 | 165.0 | 40.7 | 98.2 |

---

[*] Those taking all of their seafood from the Bay or the James.

[†] Average consumption for South Atlantic states.

[‡] Assumes no restrictions on species taken.

### b. Estimated Size of the At-Risk Population for the Consumption of Chesapeake Bay/James River Seafood

The Chesapeake Bay is an active area for sport and commercial fishing. Part of the commercial catch is marketed locally; however, much of the catch is sold elsewhere. Considering the local population as those counties and cities that are contiguous to Chesapeake Bay results in an estimated local population of 2,052,178 in Maryland and 1,004,580 in Virginia.

Table VIII-5 gives the weight of edible seafood taken from the Chesapeake Bay and its tributaries. Using the South Atlantic consumption figures given in Table VIII-1, the sports and commercial fishing catch from these water can supply the average annual requirements of 4.9 million people for finfish, 8.7 million people for crabs, 3.9 million people for clams, and 26.5 million people for oysters.

Thorslund and O'Mara (1977) have estimated the catch consumed locally (Table VIII-16). Their estimates appear to be high for oysters and crabs. Another estimate, given in Table VIII-16, assumes that the entire catch is consumed in accordance with the Marketfacts Survey results (Table VIII-1) and that the local population is 3,056,758. In this estimate 61% of the finfish are consumed locally, as are 11% of the oysters, 77% of the clams, and 34% of the crabs. These results clearly indicate that the kepone contamination of Chesapeake Bay seafood is not only a local problem but can also affect millions of people outside of the local area. As the FDA report (1977) indicates, seafood from Virginia and Maryland are sold in many eastern cities.

### 2. Kepone Exposure from Atlantic Ocean Fish

Certain species such as bluefish, spot, croaker, striped bass, striped mullet, grey trout, and speckled trout reside part time in the James River and/or Chesapeake Bay and part time in the Atlantic Ocean (Bender, 1977). Fish caught in the Atlantic after residing in these contaminated waters would also be expected to be kepone-contaminated. Unfortunately, no comprehensive evaluation has been made of the kepone concentrations in most of these species taken from the Atlantic off the shores of the Chesapeake Bay. Table VIII-17 lists the size of the commercial catch of these species: 2.9 million lb was taken, yielding an estimated edible weight of almost 1 million lb. Table VIII-18 gives the kepone concentration of the species taken from the James River, the Chesapeake Bay and, in the case of bluefish, the ocean. The FDA data shown for the Chesapeake Bay were collected at the marketplace and may include a mixture of Bay and Ocean fish. The concentration data given in Table VIII-6 imply that an average kepone concentration on the order of 0.02 to 0.04 ppm might be found for these species in the Atlantic off the shores of the Bay. If this is in fact the case and if people eat only these species as the total finfish component of their diet, this catch would supply the dietary needs of 178,000 people and would expose them to an average of 0.13 to 0.27 μg/day.

Table VIII-16

ESTIMATED PERCENT OF CHESAPEAKE BAY CATCH
CONSUMED LOCALLY

| | Source of Estimate | |
|---|---|---|
| Species | SRI | Thorslund and O'Mara (1977 |
| Finfish | 61 | 57 |
| Oysters | 11 | 72 |
| Clams | 77 | 40 |
| Blue crabs | 34 | 53 |

Because the bluefish ranges over a fairly wide area off the Atlantic coast, it was suspected that the bluefish taken from anywhere along the coast might be kepone-contaminated. As a consequence, the FDA (1977) analyzed the kepone concentration in bluefish taken as far north as Massachusetts and as far south as Florida. The average kepone concentrations as well as the commercial bluefish catch by coastal state are given in Table VIII-19. Kepone concentrations were found in bluefish

## Table VIII-17

## 1973 COMMERCIAL CATCH OF MARINE SUMMER RESIDENT FISH FROM THE ATLANTIC OCEAN OFF CHESAPEAKE BAY

| Species | Estimated Catch (lb)* | Estimated Edible Weight (lb) |
|---|---|---|
| Bluefish | 341,400 | 113,800 |
| Spot | 343,100 | 114,367 |
| Croaker | 388,700 | 129,567 |
| Mullet | 5,100 | 1,700 |
| Striped bass | 540,500 | 180,167 |
| Grey trout | 1,252,000 | 417,333 |
| Speckled trout | 1,300 | 433 |
| Total | 2,872,100 | 957,367 |

---

*Source: Pileggi and Thompson (1976).

## Table VIII-18

## KEPONE CONCENTRATIONS IN FISH THAT RESIDE IN THE JAMES RIVER IN THE SUMMER THAT MAY BE CAUGHT IN THE ATLANTIC OCEAN (PPM)

| | James River | | Chesapeake Bay | | Ocean |
|---|---|---|---|---|---|
| Species | Source 1 | Source 2 | Source 2 | Source 3 | Source 3 |
| Bluefish | 0.65 | 0.286 | 0.059 | 0.040 | 0.037 |
| Spot | 0.75 | 0.816 | 0.028 | 0.035 | -- |
| Croaker | 0.62 | -- | 0.041 | 0.032 | -- |
| Mullet | 0.37 | -- | -- | -- | -- |
| Striped bass | 0.04 | 0.382 | -- | -- | -- |
| Grey trout | 1.21 | 0.153 | 0.073 | 0.046 | -- |

---

Source 1: Bender (1977.

Source 2: Bender et al. (1977).

Source 3: FDA (1977).

## Table VIII-19

### ATLANTIC COAST BLUEFISH COMMERCIAL CATCH AND KEPONE CONCENTRATION

| State | 1973 Catch (lb)[*] | Average Kepone (ppm)[†] |
|---|---|---|
| Maine | 59,000 | NM[‡] |
| New Hampshire | -- | NM |
| Massachusetts | 556,000 | 0.014 |
| Rhode Island | 278,000 | <0.010 |
| Connecticut | 96,000 | NM |
| New York | 1,412,000 | 0.012 |
| New Jersey | 888,000 | 0.015 |
| Delaware | 3,000 | 0.020 |
| Maryland | 276,000 | NM |
| Virginia | 2,905,000 | 0.037 |
| North Carolina | 2,008,000 | 0.009 |
| South Carolina | 3,000 | NM |
| Georgia | -- | NM |
| Florida | 1,583,000 | ND[§] |

---

[*] Source: Pileggi and Thompson (1976).

[†] Source: FDA (1977).

[‡] NM - Not Measured.

[§] ND - None Detected.

as far north as Massachusetts and as far south as North Carolina. The highest average concentration (0.037 ppm) was found, as expected, for the catch taken off Virginia shores. Approximately 8.5 million lb of bluefish caught commercially from North Carolina to Massachusetts appears to be contaminated in the average range of 0.009 to 0.037 ppm.

The 1970 sportsfishing catch of bluefish off the Atlantic coast is estimated as follows (NOAA, 1973):

| Location | Catch (lb) |
|---|---|
| North Atlantic | -- |
| Middle Atlantic | 717,000 |
| South Atlantic | 12,489,000 |
| Total Atlantic | 13,206,000 |

Generally, bluefish make up only a small fraction of an individual's seafood diet. The seafood consumption survey (Nash, 1970) does not list bluefish as a separate species. People in the South Atlantic states who eat only bluefish as the finfish component of their diet would have an average kepone exposure of less than 0.25 μg/day. The commercial and sportsfishing catch could supply the entire fresh and frozen finfish requirements of 570,000 people with fish contaminated at these levels.

### 3. Kepone Exposure from Eating Fish Taken from Spring Creek, Pennsylvania

Characterization of the consumption of kepone from fish taken from Spring Creek is complicated because the extent of contamination of the entire population of fish in the creek and the extent of fishing on the creek have not been reported. Kepone concentrations of 0.025 to 0.23 ppm are reported for the fish taken near the Nease chemical plant. These concentrations could result in a kepone intake of 0.14 to 1.33 μg/day if an average consumer filled the entire finfish component of his diet with fish taken from Spring Creek. The intake could be 0.44 to 4.09 μg/day if the average person's entire seafood supply came from Spring Creek. Based on the average amount of fresh fish consumed, the average exposure would be 0.02 to 0.20 μg/day.

At most, these exposures would only apply to a relatively few sportsmen who reside locally. Even these would probably supplement their diet with seafood taken from other locations.

The Spring Creek fish are also mirex-contaminated; hence, the consumer would be exposed to both mirex and kepone.

## E. Mirex and Kepone in Mother's Milk

Tests for mirex were made of 1436 samples of mother's milk which were taken nationwide and represented all 50 states. None was found at the 30-ppb detection level. Of these samples, 298 were later tested for kepone; 9 were positive, with concentrations ranging from less than 1 to 5.8 ppb. The nine positive samples came from Alabama, Georgia, and North Carolina. Data regarding the percent found positive and kepone concentration by state are given in Table VIII-20.

The New York State Health Department will soon begin tests on several hundred pregnant women and nursing mothers in counties bordering Lake Ontario and Lake Erie to check on the level of mirex, kepone, and polychlorinated biphenyis (PCB) in their systems (Syracuse Herald-Journal, January 4, 1977).

According to Siler (1976), approximately 38% of mothers nurse their infants after they leave the hospital; the LaLeche League estimates that as many as 50% of the 3,160,000 babies born in the United States in 1974 were nursed. The number of live births for selected states are given in Table VIII-20.

Nursing may last from 2 weeks to 1 year or more. The LaLeche League recommends that the infant be nursed for the first 6 months.

Infant consumption of mother's milk has been estimated at 850 ml/day; however, this figure is based on wet nursings and is now believed to be too high. A study currently being conducted by the University of Illinois shows an average of 606 ml for the first month, 601 ml for the second month, and 625 ml for the third month for healthy infants. Bo (1976) reports consumption of 500 to 600 ml for the first 2 weeks and 700 to 800 ml for 2 weeks to 6 months for Swedish children.

## Table VIII-20

## KEPONE CONCENTRATIONS IN MOTHER'S MILK AND BIRTHS BY STATES

| State | 1974 Live Births[*] | No. Tested/ No. Positive[†] | Percent Positive[†] | Summary of Positive Data (ppb)[†] | |
|---|---|---|---|---|---|
| | | | | Average | Range |
| Virginia | 71,000 | 34/0 | 0.00 | -- | -- |
| North Carolina | 84,000 | 26/1 | 3.85 | <1.00 | <1.00 |
| South Carolina | 49,000 | 13/0 | 0.00 | -- | -- |
| Arkansas | 35,000 | 30/0 | 0.00 | -- | -- |
| Alabama | 59,000 | 94/7 | 7.45 | 3.13 | <1.00-5.80 |
| Georgia | 83,000 | 39/1 | 2.56 | 2.50 | 2.50 |
| Kentucky | 53,000 | 3/0 | 0.00 | | |
| Florida | 110,000 | 24/0 | 0.00 | -- | -- |
| Mississippi | 44,000 | 25/0 | 0.00 | -- | -- |
| Louisiana | 66,000 | 10/0 | 0.00 | -- | -- |
| Listed states | 654,000 | 298/9 | 3.02 | 2.60 | <1.00-5.80 |
| United States | 3,160,000 | | | | |

---

[*] Source: Statistical Abstracts (1976).

[†] Source: Blondell (1977).

Assuming a child consumes 600 ml/day of milk with kepone concentrations of 1 to 5.8 ppb, he would consume 0.6 to 3.5 μg/day of kepone. Assuming that the child weighs 10 lb (4.54 kg), the daily consumption is $1.3 \times 10^{-4}$ to $7.7 \times 10^{-4}$ μg kepone per gram body weight. The estimated daily exposure and at-risk population by state, assuming that one-third of the mothers nurse their babies for 6 months, is:

| State | Average Kepone Exposure (μg/day) | Estimated At-Risk Population |
|---|---|---|
| North Carolina | 0.6 | 1100 |
| Alabama | 1.9 | 1500 |
| Georgia | 1.5 | 700 |

These estimates are only relevant for the 10 states for which mother's milk has been tested. Other states might also be suspected because of past manufacturing activity, product use, and fish and other contaminated food consumption. Moreover, the sample size tested for some of the states is relatively small and therefore does not prove conclusively that kepone is not present.

Mirex contamination of cows milk may be a factor if ant bait has been applied to grazing land within the last 6 months. However, Collins et al. (1974) found mirex in cows milk only for areas treated within 3 months, but not 6 months before. Hawthorne et al. (1974a) found no mirex at the 0.3-ppb level for 60 milk samples taken from treated areas. They conclude that the milk cattle may be receiving small amounts of mirex but that not enough is present to show up in milk at residue levels above 0.3 ppb.

## F. Mirex Exposures from Foods Other Than Seafood and Mother's Milk

The available data, although not conclusive, tend to indicate that the mirex concentrations of foods, other than seafood, grown or raised commercially are free from detectable mirex contamination. The studies of beef, cows milk, and commercially raised catfish in southeastern states have confirmed the general absence of mirex. However, the findings reported by Collins et al. (1974) have shown mirex levels of 0.001 ppm in chicken eggs and 0.014 ppm in chickens taken 12 months after mirex application.

It does appear that game taken from selected southeastern states, in which mirex bait has been applied, might be mirex-contaminated. Hence, this would suggest another source (in addition to fish) of mirex to sportsmen and their families. Data given by Collins et al. (1974) show mirex concentrations as high as 0.254 ppm for cottontails, opossums, and bobwhite quail taken 6 to 12 months after mirex application. The average was about 0.07 ppm. Samples of deer adipose tissue taken 1 year after mirex application in Mississippi showed an average concentration of 0.057 ppm (Baetcke et al., 1972). Baetcke et al. (1972) also found mirex in bobwhite quail and turkey. Mirex found in birds suggest that it is present in game birds (e.g., Oklendorf et al., 1974 and Oberheu, 1972). If it is assumed that a family eats only wildgame as the meat, fish, and poultry component of its diet and that these wildgame are from contaminated areas with an average mirex concentration of 0.04 ppm,* the exposures would be as illustrated in Table VIII-21. These assumptions result in an adult exposure of 8 to 12 μg/day. These exposures, however, are believed to be gross overestimates because very few people would eat only game. Nor is it likely that all game would be taken from one contaminated area. Moreover, the mirex concentrations for contaminated game are at present, probably much less than 0.04 ppm.

According to the Household Food Consumption Survey (FDA, 1972), an average southern female consumed up to 5 g/day of game meat and an average southern male consumed up to 10 g/day of game meat. These consumptions would result in an average ingestion of up to 0.4 μg/day of mirex.

In the southeastern states during 1970, there were 1.3 million big game hunters and 2.8 million small game hunters (Fish and Wildlife Service, 1972), some of whom hunted both small and large game. Hunting success varies with the type of game, area hunted, and amount of time spent hunting. If it is assumed that of 4 million hunters, 75% capture some game and that each hunter hunts for an average of 3 people (allowing for several hunters in some families), an estimated 9 million people have some exposure to southeastern sports game that might be mirex-contaminated.

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*This estimated concentration assumes that more than 1 year has passed since the last treatment of mirex bait. State averages should be lower because many areas have not been recently treated. Moreover, because this estimated concentration is most applicable to adipose tissue, concentrations in red meat should be lower.

Table VIII-21

ESTIMATED MIREX CONSUMPTION FOR FAMILIES EATING ONLY GAME WITH A MIREX CONTAMINATION OF 0.04 PPM[*]

| Population Subgroup | Daily Mirex ( g/day) |
|---|---|
| Infant (1 year) | 2.00 |
| Male (15-17) | 11.00 |
| Female (15-17) | 8.00 |
| Male (19) | 8.56 |
| Male (35-54) | 12.00 |

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[*] Food consumption as given in Table VII-2. The calculations assume that all meat, fish, and poultry are game from contaminated areas and have a mirex concentration of 0.04 ppm.

Vegetables grown in the southeastern United States on land where mirex bait has been applied may also have been contaminated by root uptake; however, no data have been found to prove that any such vegetables actually contain mirex. Section VII-A-1 of this report indicates that plants grown in these areas may be contaminated at the order of 1 ppt. According to Table VIII-2, U.S. citizens ingest on the average of about 200 g/day per person of all types of vegetables. Assuming that these are all mirex-contaminated at the 1-ppt level would result in an average exposure of 0.2 ng/day.

Residents of Hawaii may have some exposure to mirex from its use to control the pineapple mealybug. Most wild species sampled in Hawaii for mirex are not directly consumed by humans but may indicate potential mirex concentrations present in the human food chain. Surveillance samples have shown mirex concentrations of ppb levels. Although it is rather difficult to extrapolate from these data to estimate human exposures, it might be assumed that some people would consume an average of 10 g/day of such contaminated food. This would yield daily exposures of much less than 1 μg.

## G. Kepone Exposures from Foods Other than Seafood and Mother's Milk

No data have been found to indicate that kepone has contaminated food other than seafood and mother's milk. Food that might be suspected of kepone contamination include bananas grown where kepone has been applied and chicken meat and eggs from chickens fed kepone-contaminated fishmeal. The kepone in mother's milk from North Carolina, Georgia, and Alabama probably comes from seafood; however, it may represent an, as yet, untested source such as a mirex degradation product. Kepone may also be present in imported food or food products. For example, Brewerton and Slad (1964) report on kepone residues in apples from crops that had been treated with kepone pesticides in New Zealand.

Human exposure to kepone may occur from ingesting ants that have eaten kepone bait. children, for example, may eat on purpose or ant bodies may have been mixed accidentally in foods. This type of exposure would probably occur on a one-time basis; however, because of habit or poor housekeeping, for some individuals the exposure could persist.

An ant may eat several times its own weight per day over several feedings. Assuming that a 10-mg ant eats its own weight in 0.125% kepone bait, it could contain 12.5 μg of kepone. Human exposure then might be multiples of 12.5 μg, depending on the number of ants ingested.

Residents of Puerto Rico may be exposed to kepone used to control the banana root borer. The exposure route would be from ingesting fish or animals that might be directly or indirectly contaminated. No data have been located to indicate the possible species or magnitude of concentration. It has been said that chickens are known to feed in the Puerto Rican banana fields. Some inference may be drawn as to potential concentrations in chickens from a test program where hens were fed 75- to 100-ppm kepone in their feed for 16 weeks. After 5 weeks of treatment, the kepone content of the egg yolk was 163 and 336 ppm, respectively, for the two dosage levels. After 13 weeks it was 100 and 214 ppm, respectively (Naber and Ware, 1965). Environmental sampling has been conducted in Hawaii where mirex has been used on the pineapple fields. As has been previously shown, the application of technical mirex to pineapples is much less than the application of technical kepone to bananas. The geometric mean of the amount of mirex in the Polynesian rat decreased with time from 1270 to 56 ppb. The geometric mean for residues in mongooses decreased from 2200 ppb immediately after application to 238 ppb 39 weeks later. While not conclusive, these data indicate that species of animals feeding in the banana fields may have kepone concentrations on the order of ppm levels following application.

# IX MIREX AND KEPONE IN HUMAN BODIES

The entrance and persistence of environmental concentrations of mirex and kepone in human bodies is confirmed by monitoring human tissue, blood, mother's milk, etc.

The first discoveries of mirex residues in human adipose tissue were reported by Kutz et al. (1974). Positive identifications were found in six cadavers, all of whom had resided in southeastern states; concentrations ranged from 0.16 to 5.94 ppm.

The Ecological Monitoring Branch of the Environmental Protection Agency is currently monitoring human adipose tissue for mirex and kepone. Plans are to analyze 500 samples from southeastern states. (Pesticide Chemical News, August 25, 1976.) Evaluation of the first 284 of these samples showed 52 (18%) positive. The mirex residue concentrations in the positive samples ranged between trace amounts to 1.32 ppm on a wet weight basis. By state, the number of samples and the percent for mirex are: Louisiana, 47, 40%; Mississippi, 28, 32%; Georgia, 51, 24%; Alabama, 27, 11%; South Carolina, 17, 6%; Florida, 53, 6%; Texas, 52, 0%; and North Carolina, 9, 0% (Pesticide Chemical News, October 20, 1976).

Of 1435 mother's milk samples taken throughout the country, none was shown to contain detectable concentrations of mirex. However, 9 of 298 mother's milk samples tested contained kepone. All positive samples were from southeastern states (Bondell, 1977).

Venous blood samples were drawn from 216 people who resided within 1.8 km of the Life Sciences' plant in Hopewell, Virginia. Of these 216 samples, 40 (approximately 19%) contained kepone concentrations of 5 to 50 ppb. The remaining 176 samples contained evidence of nondetectable levels of kepone; however, these levels were below the measurable levels of <5 ppb. Thirty-six of these forty positive samples were from the residential area within 0.4 km of the plant. None of the people reported having worked at either Life Sciences or the Allied Chemical Co. (U.S. EPA, 1975b).

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